ASPECTS OF THE BIOLOGY AND CONSERVATION STATUS OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS*, AND THE LUDWIG'S *NEOTIS LUDWIGII* AND STANLEY'S *N. DENHAMI STANLEYI* BUSTARDS IN SOUTHERN AFRICA

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Thesis submitted to the Faculty of Science (Percy FitzPatrick Institute of African Ornithology, Department of Zoology), University of Cape Town for the degree of Master of Science

December 1993

To my parents and to Anne

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DECLARATION

I hereby certify that this dissertation is the result of my own original research, except where otherwise expressly stated. This dissertation has not been submitted for a degree at any other university.

Signed by candidate

David George Allan

1 December 1993

ACKNOWLEDGEMENTS

I thank Prof. Roy Siegfried for having allowed me to undertake this study through the FitzPatrick Institute and for the amenities put at my disposal. My supervisor Dr Phil Hockey showed patience and a thorough attention to the manuscripts that I passed on to him. I am grateful to him for his guidance throughout this effort. I am deeply indebted to Prof. Les Underhill, who allowed me to prepare this thesis while employed at, and using the resources of, the Avian Demography Unit at the University of Cape Town. This was to the detriment of my professional work and his support was crucial. James Harrison similarly forgave me my neglect of ADU work, selflessly provided SABAP bird atlas data, and rendered other help.

Famous Grouse and the Mazda Wildlife Fund, through the Endangered Wildlife Trust and its Director Dr John Ledger, provided a vehicle and running expenses that were indispensable to the field research.

Andrew Jenkins, Wally Petersen, Carien Tugwell, Adrian Armstrong, Bozena Kalejta, Elsabe Aucamp, Anne Cohen, and Cate Brown all acted as observers on at least one road count. I hope their memories of the open plains of the Karoo and the southwestern Cape wheatlands are as indelible as are mine. Andrew Jenkins and Dr Peter Ryan were the observers on the aerial census described in Chapter 9 and Dane Gerneke ably piloted the aircraft.

René Navarro was a continual source of computer and statistical help. He was responsible for running the generalized linear model used in Chapters 3 and 4. Prof. Les Underhill similarly lent statistical advice. The work described in Chapter 7 was done in collaboration with Dr Peter Ryan, who measured the Blue Crane carcasses and conducted the morphometric analysis. His help also was central to the statistical testing of single sex grouping in Stanley's Bustards (Chapter 10). Richard Brooke gave me useful insights into historical records and moult patterns. Dr Morné du Plessis, Prof. Tim Crowe, Dr Rob Little, and George Boobyer were reliable sources of stimulating discussion and encouragement. Alison Joubert kindly extracted the rainfall data used in Chapter 9. Andrea Plös was instrumental in helping with the production of most of the maps presented in this thesis. George Underhill made the nest record card collection of the Southern African Ornithological Society available to me. Bozena Kalejta, Cynthia Best and Felicia Stoch rendered help at various times with word-processing and graphics computer packages, and Dr Terry Oatley allowed me the use of his computer for the preparation of graphics. Dr Mike Knight provided me with a copy of program TRANSECT and Brian Tibbles helped with STATGRAPHICS.

I am grateful to the following for their comments on various draft texts of this thesis: Dr Phil Hockey, Prof. Les Underhill, Dr André Boshoff, Richard Brooke, Richard Dean, Dr Peter Ryan, and Carl Vernon.

Dr Warwick Tarboton introduced me to the fascination of cranes and bustards. The other 'crane and bustard people' whom I have been priviliged to know have been a constant source of encouragement. They include Dr Dave Johnson, Bill Barnes, Don Porter, Ann Scott, Carl Vernon, Rob Filmer, Elsabe Aucamp, Mark Boobyer, Lindy Rodwell, Wicus Leeuwner, and, especially, Dr George Archibald.

My thanks go to the many people who provided me with records of cranes, and especially, bustards over the years and to the landowners who co-operated with my study. The data provided by Ann Scott were particularly useful.

I thank my parents and my brother Geoffrey for their unquestioning support extending over a lifetime. My greatest indebtedness and appreciation go to Anne Cohen; she made my house a home during the entire period this thesis was written. Without the inspiration she brought to my life, the task would have been left uncompleted.

ABSTRACT

The cranes (Gruidae) and bustards (Otididae) are highly threatened taxa. Many species are on the brink of extinction due to anthropogenic factors. On the positive side, several species show a remarkable ability to adapt to man-modified environments. If the cranes and bustards are to survive through the coming century, research on the aspects of their biology directly relevant to understanding their conservation requirements is a high priority. Without a reliable and relevant base of knowledge, no successful conservation management plan can be devised for each threatened species. This thesis presents information on three threatened members of these taxa in southern Africa, the Blue Crane *Anthropoides paradiseus*, and Ludwig's *Neotis ludwigii* and Stanley's *N. denhami stanleyi* Bustards. This information furthers our understanding of their conservation status.

The thesis begins with a detailed review of the phylogeny, general biology and conservation status of cranes. This is necessitated by the absence of any thorough and recent review being available. The review provides a point of reference for the research results on the Blue Crane presented in the following seven chapters.

Research on the Blue Crane largely focuses on the southwestern Cape and Karoo regions. The past and present distribution of the species in southern Africa is outlined and related to various vegetation types and the effect of various anthropogenic influences. Its colonization of the southwestern Cape is a particularly interesting finding. The abundance of the species in various parts of South Africa is discussed, largely based on road counts and bird atlas data. The total population size in South Africa is estimated and the previously unrecognised importance to the species of the southern Cape coastal plain between Botrivier and Mossel Bay is highlighted. The scarcity of Blue Cranes in the western part of the southwestern Cape, compared with the southern part, is quantified. The reasons for this anomolous dichotomy in abundance between these two superficially similar areas are unclear and worthy of further investigation.

Published statements as to the movements of Blue Cranes in South Africa are reviewed and found to be contradictory. Bird atlas data is shown to be of little use in elucidating Blue Crane movements, due to the confounding effect of seasonal changes in group sizes. This latter finding is novel and has profound implications for the interpretation of bird atlas data based on the use of reporting rates. The species is demonstrated to have obvious movements into and out of the southern Cape. Its movements elsewhere in South Africa, however, remain obscure and there is evidence that its patterns of movements have altered over time, at least in the Cape Province. Further research in this regard is a high priority.

The population structure of the Blue Crane is typical of crane species and is characterised by a high proportion of non-breeding individuals. A brief synthesis of the

breeding habits of the species is provided, along with extensive data on the proportion of juveniles in Blue Crane populations in the Karoo and southwestern Cape. The habitat selection of Blue Cranes in the Karoo and southwestern Cape is examined. This analysis highlights the dichotomy in the habitat selection of the species in these two regions. In the Karoo, Blue Cranes inhabit natural vegetation, while in the southwestern Cape they virtually are restricted to cultivated pastures and agricultural crop fields.

During the course of this study, a large sample of Blue Crane carcasses became available after a mass poisoning incident in the southern Cape. These carcasses allow a detailed examination of the morphometrics, sex ratios, moult of the remiges, and stomach contents of Blue Cranes in this region. Males are larger than females, but there is wide overlap between the sexes in measurements. The sex ratio is even. Primaries usually, but not invariably, appear to be moulted simultaneously, but moult of the secondaries is more complex, perhaps with sexual differences. Further information on the diet of the species, including seasonal changes in diet, are required.

The final chapter on Blue Cranes is a comparison of the abundance of the species in the Cape Province between the periods 1965-1966 and 1987-1993, based on road counts. No evidence for any decrease in numbers could be found in the Karoo. There has been a dramatic increase in the southern Cape between these two time periods. This position in the southwestern Cape and Karoo contrasts strongly with evidence for major decreases in numbers in the grassland biome elsewhere in South Africa. The major threats to Blue Cranes are identified. Poisoning incidents involving all three species of cranes in South Africa are documented.

The examination of Ludwig's and Stanley's Bustards is more cursory and a single chapter is devoted to each species. The focus of research on Ludwig's Bustard is on its abundance and movements in southern Africa, using bird atlas data, road counts, an aerial census, and landowners' comments. The winter movement of Ludwig's Bustard into the winter rainfall Karoo is confirmed. Information is provided showing that these movements are fine-tuned and sensitive to local rainfall patterns. A previously unsuspected movement between the Namib and Namibian Escarpment regions is identified. No evidence, however, could be found that the species decreases in abundance in the summer rainfall Karoo during the winter. Possible reasons for this are discussed. A total population estimate for Ludwig's Bustard is provided. The comparison of atlas reporting rates and other measures of abundance in this chapter provide the first statistically rigorous confirmation that differences in reporting rates reliably reflect differences in bird abundance.

The final chapter of the thesis examines the abundance, population structure, including sex ratio, habitat selection, and conservation status of Stanley's Bustard. Most of the data presented come from the southern Cape study area, and are based on road

counts and information elicited from volunteer observers recruited through an appeal in the conservation media. A total population estimate in the southern Cape is given, based on line transect counts. That Stanley's Bustards are absent from the western parts of the southwestern Cape and the succulent Karoo, and are scarce in the Nama Karoo is confirmed. The sex ratio is biased towards females and both sexes tend to form single sex groups. There was an interesting seasonal pattern of habitat selection, with the birds moving to natural vegetation during the breeding season and favouring cultivated pastures and harvested cereal crop fields during the non-breeding season.

PART ONE

THE BIOLOGY AND CONSERVATION STATUS OF THE BLUE CRANE

CHAPTER 1

THE BIOLOGY AND CONSERVATION STATUS OF CRANES (GRUIDAE)

CHAPTER 1

THE BIOLOGY AND CONSERVATION STATUS OF CRANES (GRUIDAE)

SUMMARY

There is no recent and detailed review of the cranes (Gruidae). This chapter provides such a review, concentrating on the phylogeny, general biology, and conservation of the group. Concerning their general biology, particular attention is paid to the morphology, distribution, foraging habitat, diet, roosts, movements, flocking, territoriality, longevity and, especially, the breeding habits of these birds. This review provides a context for the results presented in later chapters of a study on the Blue Crane Anthropoides paradiseus.

The taxonomic incorporation of the cranes in the order Gruiformes has been confirmed by DNA-DNA hybridization studies, which have also confirmed their close relationship with the bustards (Otidides). The closest relative of the Blue Crane is the Demoiselle Crane Anthropoides virgo, *and both species differ from other cranes in their emancipation from wetland habitats. Most species have distinctively-coloured and patterned heads but the Blue Crane is the plainest of the group in this regard. The elongated and convoluted trachea of cranes allows their characteristically far-carrying vocalizations. Cranes do not show obvious sexual dimorphism. Juvenile (first year) cranes resemble adults but can be recognised from other age classes by subtle cues. Cranes are found on all continents, except South America and Antarctica, with Asia boasting the greatest diversity of species. Africa supports four breeding species and an additional two species which occur as non-breeding migrants. Three species occur in southern Africa, all as breeding species.*

Most cranes characteristically feed in wetlands but the Blue and Demoiselle Cranes are major exceptions and typically forage in dry habitats throughout the year. Most other species, however, also will forage in drylands, including crop fields, especially out of the breeding season. Cranes are omnivorous but most species are largely vegetarian, especially in the non-breeding period, and their carnivorous habits appear to have been over-estimated by many authorities. All cranes, including the Blue and Demoiselle Cranes, show a strong preference for roosting overnight in shallow waterbodies.

Most cranes of temperate regions are highly migratory but those of more tropical regions show wide variation in the extent of their movements, from being totally sedentary, to evidencing nomadism, and regular or partial migration, including altitudinal migration. There are intraspecific differences in the extent of movements shown by many species. Breeding pairs of cranes defend territories, at least during the breeding period. Flocking is characteristic of cranes which are not breeding and the large proportion of non-breeding, but apparently adult, individuals in crane populations

Two unusual taxa, the Limpkin *Aramus guarauna* and the sungrebes or finfoots, *Podica senegalensis*, *Heliopais personata* and *Heliornis fulica*, appear to be the closest living relatives to the cranes. Sibley & Ahlquist (1990) place them in the same superfamily (Gruoidea) as the cranes. The three extant species of trumpeters *Psophia*, superfamily Psophioidea, share the same parvorder (Gruida) as the cranes, Limpkin and

ensures that flocks occur throughout the year. Cranes show prolonged longevity and wild individuals of at least 20 years of age are known.

Cranes are monogamous and pair bonds, once firmly established, probably are life-long, with mated pairs remaining in close proximity to one another throughout the year, even when they join flocks. Age of first breeding is delayed and successful breeding

hybridization have occurred in the smallest and most isolated populations. Indeed, the Wattled Cranes involved in at least two of the incidents apparently were offspring of nearby single Wattled Crane pairs that, by then, were isolated from other conspecifics by distances of more than 100 km. This was brought about by habitat destruction in the intervening areas. The extent to which these incidents are 'natural' therefore is questionable, and they may reflect the anthropogenically-induced isolation of these offspring from conspecifics.

Hybridization in the wild, with the production of viable offspring, has also been reported in other cranes, for example, between Hooded and Eurasian Cranes (Nishida 1981) and between Sarus and Australian Cranes (Archibald 1981b). Sarus /Australian Crane hybrids appear to be fertile and apparently have mated in the wild with Sarus Cranes to produce viable offspring.

1.3) *Biology of cranes*

Morphology

Cranes are amongst the tallest of flying birds and the Sarus Crane holds the avian record in this regard (Archibald *et al.* 1981). It follows that they are characterized by their long necks and legs. Most species have distinctively-coloured head and facial features. These usually involve the combination of areas of red plumage, or exposed patches of red skin, surrounded by black, grey and white plumage, occasionally accompanied by pronounced wattles and ornate crests. The Blue Crane is an exception and has the least patterned head relative to other cranes. The feathering at the rear of the head in adults of this species, however, is elongated, resulting in a distinctive bulbous appearance (Johnsgard 1983). Crane bills are long and straight, and are used for pecking at, or digging for, food. Another typical feature of cranes, although not the crowned cranes, is their elongated and convoluted trachea. This allows them to produce resonant and bugle-like vocalizations. Cranes are not characterized by obvious sexual dimorphism; males and females are similar in size and plumage. Juvenile (first year) cranes resemble adults but in most, if not all, species they can be recognised by relatively subtle differences (e.g. Lewis 1979a for the Sandhill Crane). These can involve the colour, pattern and even length of at least elements of their plumage, their size, the colouration of their bare parts, and their vocalizations.

Distribution

Cranes are found on all the world's continents, except for South America and Antarctica. Asia boasts the highest diversity, with eight breeding species. Two of these, the Demoiselle and Eurasian Cranes, also extend into Europe (western Palaearctic) as breeding species. There also is a small, isolated breeding population of

the former species in northeastern Africa (Cramp & Simmons 1980, Urban 1988). Australia has two breeding species, one of which, the Sarus Crane, is shared with Asia. North America is inhabited by two breeding species, the Whooping and Sandhill Cranes. The breeding range of the latter extends into northeastern Siberia (Cramp & Simmons 1980) and therefore it could be considered as a ninth Asian breeding species. Sub-Saharan Africa supports four breeding species, the Black Crowned, Grey Crowned, Blue and Wattled Cranes. In addition, a further two species, the Demoiselle and Eurasian Cranes, are nonbreeding migrants to northeastern sub-Saharan Africa.

Foraging habitat

Most cranes characteristically feed in wetlands. Blue and Demoiselle Cranes are the major exceptions. These two species typically occur in dry habitats. All species, except for the Siberian Crane (Archibald *et al.* 1981), however, will forage in drylands, including crop fields, occasionally or even regularly, especially out of the breeding season (Johnsgard 1983).

The exploitation of man-made crop fields as foraging habitats has been subject to intensive research in the Sandhill Crane (e.g. Lovvorn & Kirkpatrick 1982a, Krapu *et al.* 1984, Iverson *et al.* 1985, Littlefield 1986, Reinecke & Krapu 1986, Iverson *et al.* 1987, Sugden *et al.* 1988) and, to a lesser extent, the Eurasian and Demoiselle Cranes (Alonso, Alonso & Veiga 1984, Alonso, Alonso & Veiga 1987, Alonso, Veiga & Alonso 1987, Khachar *et al.* 1991).

The motivation for these investigations has been driven largely by three factors. Firstly, the perceived or actual economic damage caused to farmers through crop depredations by cranes. Numerous studies mention this problem, e.g. for the Grey Crowned, Eurasian, Hooded, Whitenaped, Blue and Sandhill Cranes (Pomeroy 1980, Archibald *et al.* 1981, Nishida 1981, van Ee 1981, Walkinshaw 1981a, Geldenhuys 1984, Tarboton 1984, 1992a, Johnson & Barnes 1986, Morris 1987, Filmer & Holshausen 1992, Johnson 1992a, 1992b, Stretton 1992, Vernon *et al.* 1992, Youhui 1991). Secondly, the potential relevance of the use of crop fields to the threatened conservation status of at least some populations of these species. Thirdly, in the case of the Sandhill Crane, the significance of these habitats to the management of this species as a legally hunted gamebird. The decision to re-instate the Sandhill Crane as a gamebird was based chiefly on crop damage caused by these birds (Stephen *et al.* 1966, Miller *et al.* 1972).

Diet

Cranes are omnivorous, eating both vegetable and animal (mainly invertebrate) matter. They are largely vegetarian, however, and their carnivorous habits appear to

have been over-estimated, or at least over-stressed, by some observers. In fact, an examination of the species accounts in Johnsgard (1983) confirms that vegetable matter predominates in at least 13 species. Only two species, the Whooping and Redcrowned Cranes, reportedly favour invertebrates, although both also take plant material. In the former species, diet has been studied only on the nonbreeding grounds (Hunt & Slack 1989), while the diet of the latter is poorly known and requires further study to confirm the alleged preference for animal food. Cranes chicks of all species, however, appear to be fed largely on small invertebrates.

All species, except for the Siberian Crane, occasionally or regularly, indeed during some periods virtually exclusively, feed on crops, e.g. wheat, corn, rice, sorghum, barley, oats, rye, sunflowers, peanuts, soya beans, beans, peas, cabbages, spinach, lucerne, etc. (Pomeroy 1980, Johnsgard 1983, Reinecke & Krapu 1986, Alonso & Alonso 1991, Fulin 1991, Youhui 1991). Cereal crops are particularly favoured and the birds usually glean fallen seeds in harvested fields. The Eurasian Crane seems unusual in regularly feeding on crops which grow below ground and must be probed for and unearthed, i.e. potatoes, sweet potatoes, carrots, beets and radishes (Swanberg 1987, Fulin 1991, Lan 1991, Youhui 1991). An experimental study (Sugden & Clark 1988) showed that Sandhill Cranes prefer some cereal crops to others. Sometimes this habit brings them into conflict with man and renders them vulnerable to intentional or inadvertant poisoning. Crop damage is not just restricted to feeding on these plants, but also results from trampling, especially during display dancing, and uprooting while searching for invertebrate prey. Exploitation of these unnatural foods is most common during the nonbreeding period in most wetland dependent species. The habit has obvious economic, conservation and management implications.

Detailed dietary analyses exist only for the Sandhill Crane. One study (Mullins & Bizeau 1978) of the diet of this species on its breeding grounds, drawn from gizzard contents, found that natural plant material comprised 73% by volume and the remaining 27% consisted of invertebrate matter. Another study of diet during the nonbreeding season (Reinecke & Krapu 1986), based on gut contents, found that plant material comprised 97% by dry weight, exclusively cultivated corn, the remainder being invertebrates. This latter study found that the birds foraged for prolonged periods in natural grasslands and lucerne fields to obtain the relatively small proportion of invertebrates consumed, which they suggest are essential to compensate for the protein and calcium deficiencies in corn. In addition, the birds ate small amounts of lucerne shoots, which also are rich in protein. Mixed farming of crops (cultivated corn) and livestock (natural and lucerne grazing lands) therefore was important for providing suitable foraging habitat for this species. The shortage of natural grasslands limits Sandhill Crane numbers on the nonbreeding grounds.

A further study on the nonbreeding diet from another locality (Hunt & Slack 1989), based on an analysis of faecal samples, found vegetable matter to comprise 98% by volume and invertebrate matter 2%. Although the plant material consumed consisted almost entirely of natural plants (acorns *Quercus virginiana* and wolfberry *Lycium virginiana*), cultivated grains were the major diet in the region and the samples analysed, which came from a protected wetland reserve, were from birds which temporarily visited the site to feed on natural vegetation rich in nutrients (ascorbic acid, iron, calcium, and amino acids) that are absent from corn, the main dietary component. These studies suggest that the heavy reliance of cranes on cultivated crops, which are poor in certain nutrients, could have significant physiological consequences for these birds.

Roosts

All cranes, including Blue and Demoiselle Cranes, show a strong preference for roosting communally at night in shallow waterbodies. The crowned cranes are unique in regularly roosting in trees (Walkinshaw 1964, Pomeroy 1980, Frame 1982, Urban *et al.* 1986, Urban 1987) and even on wooden or steel overhead transmission structures (pers. obs in the Transvaal and Transkei, South Africa).

Detailed investigations have been carried out on the characteristics and use of roosts by Sandhill (e.g. Lovvorn & Kirkpatrick 1981, Melvin & Temple 1983, Krapu *et al.* 1984, Iverson *et al.* 1985, Littlefield 1986, Iverson *et al.* 1987, Sugden *et al* 1988, Folk & Tacha 1990, Pogson & Lindstedt 1991), Eurasian (Alonso, Alonso & Veiga 1984, Alonso *et al.* 1985, Alonso, Alonso & Veiga 1987, Alonso, Veiga & Alonso 1987), and Hooded (Kawamura 1981) Cranes. These studies have been spurred by the demonstrated importance of roosts in dictating the habits of cranes. These include their patterns of large-scale distribution, abundance, local dispersion, and use of foraging habitats. The spatial concentration of large numbers of cranes inherent to their use of communal roosts has obvious significance, relevant to crop damage, conservation and management. Cranes show flexibility in their use of roosts and can adapt to using artificial or human regulated waterbodies and to anthropogenic changes in roost availability (Lovvorn & Kirkpatrick 1981, Pogson & Lindstedt 1991). Archibald *et al.* (1981) and Kawamura (1991) stress the importance of secure roosting sites in the conservation of cranes.

Movements

Most cranes inhabiting temperate regions are strongly migratory, with widely disjunct breeding and wintering ranges. Cranes typically concentrate at traditional localities prior to, and during, migration, and the term 'staging areas' has been coined

for these sites (Krapu 1987). Tropical species are more sedentary but can show marked local movements and some nomadism, although the extent of these can differ between populations of the same species. Some of the movements shown by tropical cranes are between large wetland systems, others apparently are seasonal altitudinal movements, and some are related to drought conditions. For example, a low level of vagrancy has been reported for the Grey Crowned Crane in South Africa (Geldenhuys 1984, Tarboton 1992a). Many of the Wattled Cranes breeding in the vast Kafue Flats of southern Zambia frequently visit the Makgadikgadi wetlands in northern Botswana but the extent of this movement varies between years (Konrad 1981). By contrast, the Transvaal population in South Africa is wholly sedentary (Tarboton 1984). Altitudinal movements have been reported for the Blue Crane in Natal, South Africa (Walkinshaw 1963, 1973). Movements related to drought conditions occur in the Australian Crane (Blackman 1978, in Johnsgard 1983).

Extreme variation in the extent of migration can occur even in temperate species. For example, the Sandhill Crane has some populations which annually migrate over thousands of kilometres between their breeding grounds in the Arctic tundra and the southern United States, while the southernmost breeding populations are entirely sedentary (Drewein & Lewis 1987). Cranes also show adaptability in their patterns of movements in response to man-made influences. These responses include alterations to migratory routes, stopovers and timing (Littlefield 1986, Fulin 1991, Pogson & Lindstedt 1991, Genard & Lanusse 1992). Eurasian Cranes which used to winter largely in northwestern Africa now spend most of the winter in Spain due to habitat destruction in the former area and increased cereal farming in the latter region (Alonso, Veiga & Alonso 1987). The Japanese population of the Redcrowned Crane has ceased to migrate from the breeding areas in winter, due to the artificial provisioning of food during these months, and is now essentially sedentary (Johnsgard 1983). This represents the most anthropogenically induced alteration of migratory habits by this family.

Gruine cranes employ a combination of soaring, downward gliding and flapping flight when migrating and undertaking other, short-distance movements (Pennycuick *et al.* 1979, Johnsgard 1983, Kuyt 1987, Williams *et al.* 1991). Blue Cranes soar regularly (Maclean 1993, Urban *et al.* 1986, pers. obs). Pennycuick *et al.* (1979) state that it is unclear whether the crowned cranes soar. During the period 1982-1992, details of 178 observations of Grey Crowned Cranes were recorded in the Transvaal and Transkei, South Africa, including 21 observations of birds in flight (pers. obs.). In no instance was soaring flight observed.

Migratory flights, and even flights between foraging areas and roosts, in at least some cranes, occur occasionally and even regularly at night (Pennycuick *et al.* 1979,

Lovvorn & Kirkpatrick 1981, Nesbitt & Hintermister 1984, Alonso *et al.* 1985, Urban *et al.* 1986, Kovshar 1987, Deppe 1991, Williams *et al.* 1991).

Flocking

Most cranes are gregarious in the nonbreeding season. Flocking is characteristic, particularly in migratory species, and can involve hundreds or even thousands of individuals. The foraging and predator detection advantages of flocking in the Eurasian Crane are discussed by Alonso & Alonso (1991). The term 'floaters' has been coined for flocks of unmated cranes, i.e. immatures and unmated adults (Tarboton 1984, Tarboton, Barnes & Johnson 1987). Flocks of nonbreeding cranes can be found at all times of year, including during the breeding season, and can comprise a substantial proportion of the total population (Appendix 1.1). For most species the proportion of nonbreeders is based on counts of cranes not isolated in pairs during the breeding season. Nonbreeders comprise 50% or more of the population in most species. The data presented for the Grey Crowned Crane in East Africa and the Wattled Crane are confounded by the protracted breeding seasons of these species (Irwin 1981, Konrad 1981, Pomeroy 1987, Tarboton, Barnes & Johnson 1987), i.e. many pairs that bred at times other than when some of the counts were made could have been in apparent flocks of nonbreeders when counted. This problem is likely to affect the assessment of the proportion of nonbreeders in other species as well, but probably to a lesser extent.

The significance of high numbers of nonbreeders to the conservation status of cranes has been discussed by Tarboton, Barnes & Johnson (1987). On the one hand, it may represent a healthy surplus of individuals precluded from breeding by saturation of the breeding habitat by established pairs. On the other hand, it may represent large numbers of breeding birds temporarily or permanently displaced from their breeding sites by droughts or wetland destruction.

Many studies show that flocks of cranes are unstable social units, with flocks regularly splitting up or merging with other groups (e.g. Pennycuick *et al.* 1979 and Tacha 1988). For example, observed flock sizes tend to vary with time of day (Miller & Stephen 1966, Alonso, Veiga & Alonso 1987). Mated pairs and family groups, however, are highly stable and the individuals comprising such groups remain in close proximity to one another, even when within large flocks (Miller & Stephen 1966, Lovvorn & Kirkpatrick 1982b, Layne 1983, Tacha 1988, Tacha & Vohs 1984).

Territoriality

The extent of territoriality while breeding is poorly known for most species. Nests, however, usually are well spaced (Johnsgard 1983) but occasionally are sited close together (e.g. Masterson 1986). Mated pairs of non-migratory Sandhill Cranes defend

territories, while unmated adults do not establish territories (Nesbitt & Williams 1990). Some mated pairs remain on their territories throughout the year, while others vacate their territories during the postbreeding period. During the period after breeding, these cranes regularly feed in dryland habitats. Pairs having dryland habitats within their territories remain resident, while those without such habitat in their territories vacate them to flock with other cranes in dryland areas. Territoriality by family groups on the nonbreeding grounds has been found in the Whooping (Allen 1952, Blankinship 1976), Hooded (Kawamura 1987), and Siberian (Sauey 1987) Cranes. In the Hooded Crane (Eguchi *et al.* 1991) the protection of a food supply for the juveniles has been suggested as the reason for territoriality in the wintering quarters.

Longevity

Wild cranes probably are long-lived, a feature suggested by their low breeding productivity and age of first breeding (see under 'Breeding' below). Sufficient data from studies employing individually marked birds to confirm longevity exist only for the Sandhill Crane, and, even for this species, the relevant information is meagre. Ringing data suggest an annual mortality rate of about 22% and a population turnover rate of about 15 years (Johnsgard 1983). These ringing data, however, probably are not representative of wild crane populations, as many recoveries came from hunted birds. Johnsgard's analysis is aimed at stressing the potential over-harvesting of this species, rather than at examining natural survival rates and longevity of wild crane populations *per se*. He does, however, identify two further biases inherent to such ringing studies of long-lived species, i.e. ringed birds surviving beyond the analysis period and ring loss, which would inflate mortality estimates. In one study using marked Sandhill Cranes (Tacha *et al.* 1989) five individuals survived for at least nine years, and in another (Nesbitt 1992) some individuals that were at least 19 years old were still breeding successfully.

A colour-ringing study of Hooded and Whitenaped Cranes (Ozaki 1991) showed that 70% and 78% respectively of cranes colour-ringed on the wintering grounds returned the following year. A higher proportion of adults (78% and 82% respectively) were seen the following year, compared to juveniles (60% and 70% respectively).

A model of survivorship in the Whooping Crane (Binkley & Miller 1980), based on counts of adults and juveniles on the wintering grounds, suggested that mortality is high in the first year (almost 40%), drops off dramatically in the second year, then rises slowly (to about 10%) in the 15th year, when it accelerates dramatically to reach about 50% in the 22nd year. They suggest a maximum longevity of 22-24 years. A recent study suggests that mortality in this species appears to be highest during migration (Lewis 1991).

Captive cranes typically live for long periods. Johnsgard (1983) shows that survival in captivity beyond 20 years is regular. A Siberian Crane, which lived for 82 years in captivity, evidenced the longest known lifespan of any bird (Matthews & McWhirter 1992). These records demonstrate the potential for extended longevity in wild cranes.

Breeding

Mating system and age of first breeding

Cranes are monogamous, probably with life-long pair bonds (Nesbitt & Wenner 1987, Tacha 1988). Mated pairs remain together throughout the year. 'Divorce', however, has been recorded in the Sandhill Crane (Littlefield 1981a).

Most cranes probably do not breed until they are two to five years old (Cramp & Simmons 1980), but age of first breeding in the wild has only been intensively investigated for the Sandhill Crane. Pair bonds in this species are initiated within flocks of nonbreeders (Nesbitt & Wenner 1987, Nesbitt 1989, 1992). Initial pairings occur at the end of a crane's second year, and are followed by breeding attempts early in the third year. These, however, are usually ephemeral and the typical sub-adult pairs five times with different individuals before breeding successfully. The earliest and mean age of successful breeding is three and five years respectively, in both migratory (Greater Sandhill Cranes) and sedentary (Florida Sandhill Cranes) populations. The modal age of first successful breeding, however, was five years in sedentary populations and four years in migratory populations. The duration of pair bonds was related to breeding success. Pairs that did not breed successfully in their initial breeding attempts frequently separated, while those that were successful tended to remain together, even if they failed in subsequent breeding attempts.

Another study (Tacha *et al.* 1984) also found that pair bonds were formed in flocks of nonbreeders. Tacha *et al.* (1989) studied age of first breeding in a different population of migratory Sandhill Cranes (Lesser Sandhill Cranes). They found the earliest age of pairing to be three years old, 20% of individuals were paired by four years old, most formed pair bonds during their fifth or sixth years, and virtually all were paired by age eight. The earliest age of first successful reproduction was five years but most individuals did not breed successfully until they were seven or eight years old.

First, but unsuccessful, breeding (egglaying) by two pairs of three year old birds has been found in wild Whooping Cranes (Kuyt 1981).

Nest sites

Most cranes nest in wetlands, sometimes man-made (e.g. White 1987 for the Australian Crane), constructing a nest mound of wetland vegetation to raise the eggs

above water level. The Blue and Demoiselle Cranes are exceptions. These two species, in addition to being independent of wetlands for foraging, also nest in dryland habitats. Eggs are laid directly on the ground, with little or no nesting material involved (Walkinshaw 1963, Xueming & Junchang 1991). Both species occasionally line the nest scrape with small stones (Walkinshaw 1963, Johnsgard 1983, Schoff 1991). Demoiselle Cranes breed in agricultural fields in some parts of their range (Kovshar 1987, Winter 1991). The Sandhill Crane, the nests of which are usually restricted to wetland sites, occasionally nests in dry situations (Layne 1982, Toland 1991). About 50% of Mississippi Sandhill Crane nests are on dry ground but always adjacent to wetland habitats (Valentine 1981). Cuban Sandhill Cranes characteristically nest, and even forage, virtually entirely in dry situations (Walkinshaw 1953). Grey Crowned Cranes, remarkably, have been recorded nesting occasionally in trees, and in at least two of three southern African records the abandoned stick nests of other large birds were used (Steyn & Ellman-Brown 1974, Lees 1977).

Eggs

The eggs of gruine cranes are richly coloured and patterned, but those of the crowned cranes are plain white.

Clutch sizes

Studies of captive birds show that cranes are indeterminate layers and that individual females can be induced to lay 8-9 eggs by removing eggs as they are laid. Up to 17 eggs have been elicited from a single female during the course of one breeding season using this method (Derrickson & Carpenter 1987).

The typical clutch size of most wild gruine cranes is remarkably consistent between species and usually comprises two eggs, sometimes one, and very rarely three (Appendix 1.2). The data on clutch sizes presented in Johnsgard (1983) have been included in Appendix 1.2.

How many of the observed single egg clutches represent incomplete clutches is unclear in most studies. Crane eggs within clutches are laid two to four days apart (Cramp & Simmons 1980) and therefore many observations of single eggs may be of incomplete clutches (Thompson 1970). Indeed, as the incubation period in most cranes is approximately 30 days (Johnsgard 1983) and eggs usually are laid two days apart, about 7% of clutches examined could be expected to be incomplete. The problem of accurately determining clutch sizes is highlighted by examples of Sandhill Crane nests from which one of the two eggs disappeared during incubation (Thompson 1970). Another instance of a three egg clutch in the Sandhill Crane was attributed to two females laying in the same nest (Littlefield 1981b).

The clutch sizes of Wattled and crowned cranes are exceptions to the typical two-egg clutch of cranes. The former regularly lays a single egg, and the crowned cranes regularly lay three, and occasionally even four, eggs per clutch (Appendix 1.2). The eggs in single-egg clutches of Wattled Cranes are significantly heavier than the eggs in two-egg clutches (Johnson & Barnes 1991).

Replacement clutches

Johnsgard (1983) states that the laying of repeat clutches to replace earlier eggs or broods lost is unusual in cranes. This may be incorrect. In the sedentary Florida Sandhill Crane, 77% of pairs that failed after egglaying during their first breeding attempt laid a second clutch, and 80% that failed during their second attempt laid a third clutch (Nesbitt 1988). One pair even laid a fourth clutch. Repeat clutches were laid within 18-20 days of the loss of the previous clutch. Later clutches were more successful than earlier ones and renesting did not affect clutch size or fertility. In a different population of this subspecies, 70% of pairs that failed during their first attempt laid a second clutch, and that 29-40% that failed during their second attempt laid a third clutch (Bennett & Bennett 1990). Repeat clutches were laid within 7-25 days. There was no significant difference in clutch size or hatching success between earlier and later clutches, but brood success was significantly higher for later broods. In a third population of this subspecies, an estimated 21% of breeding attempts were repeat attempts (Dwyer & Tanner 1992).

Second and third clutches also have been found in the Eurasian Crane (Cramp & Simmons 1980, Neumann 1987). Repeat clutches have been recorded for the Wattled Crane in the Transvaal (Tarboton 1984) and Natal (Johnson & Barnes 1991). In the latter area, a third clutch after two successive failures in the same breeding season was observed and repeat nesting after failure was found to be usual and occurred soon after the earlier failure. The success of repeat clutches was similar to that of first clutches in Natal. There was some evidence that repeat clutches were larger than initial clutches, i.e. more likely to comprise two eggs. Repeat clutches have been reported for at least the Grey Crowned (Pomeroy 1980, Mafabi 1991), Whitenaped (Liying *et al.* 1991), Redcrowned (Jie *et al.* 1991), and Blue (Tarboton 1976) Cranes. No difference in fertility, or weights, between the eggs in first and subsequent clutches has been reported in the Redcrowned Crane during artificial manipulation (Jie *et al.* 1991). Whooping Cranes, however, apparently rarely replace lost clutches (Kuyt 1981).

Young

Crane chicks are precocial and nidifugous and can leave their nest sites and accompany their parents within at least two days of hatching (Cramp & Simmons 1980).

Brood sizes

Data on brood sizes in cranes are presented in Appendix 1.3. The Whooping, Wattled and Siberian Cranes have been excluded from Appendix 1.3, as these three species usually rear only a single young per breeding attempt (Novakowski 1966, Flint & Kistchinski 1981, Konrad 1981, Tarboton, Barnes & Johnson 1987). Whooping Cranes, however, have been subject to the removal of single eggs from two-egg clutches during management and prior to this 14,5% of pairs on the wintering grounds were accompanied by two young (Walkinshaw 1973). Wattled Crane pairs with broods of two chicks have been seen twice in Malawi (Collar & Stuart 1985), and two pairs out of 117 pairs with fledged young had two chicks in Zambia (Benson & Pitman 1964). On only two occasions have Siberian Crane pairs on the wintering grounds been accompanied by two young (Zhigang *et al.* 1991). 'Adopted' juveniles (Masatomi 1972) could be the explanation for families of more than three members in these species.

Miller (1973) discusses brood size in the Whooping and Sandhill Cranes. In the Whooping Crane, citing Novakowski (1966), he attributes the loss of the second hatched chick under natural conditions to its being abandoned by the parents. The Wattled Crane appears similar to the Whooping Crane in this regard. Only a single young is reared per breeding attempt, despite two eggs regularly being laid (Konrad 1981). In this species, the second egg is abandoned as soon as the first hatches (Tarboton, Barnes & Johnson 1987, Johnson & Barnes 1991). In captivity, strong inter-chick aggression has been noted in this species (Abrey 1992). Sibling aggression in the Whooping Crane may be implicated in the loss of the second chick (Erickson & Derrickson 1981). Siberian Cranes also rarely raise more than a single chick per brood, and this has been attributed to sibling aggression (Flint & Kistchinski 1981, Bin & Zuoyi 1991). Putnam & Archibald (1987) state that chicks of this species show the most intense and prolonged inter-chick aggression, relative to other cranes.

In the Sandhill Crane, Miller (1973) attributes the loss of the second chick to sibling aggression. He states that the raising of two young is 'not common'. The evidence he provides to support this is his observation that of 623 wintering families of Lesser Sandhill Cranes, only one pair had two young and an 'adopted' young was possibly involved in that instance. He cites the observations by Hyde (1957) and Walkinshaw (1965a) of sibling aggression in the wild and several unpublished reports for captive birds. Walkinshaw (1981a) and Miller *et al.* (1972) repeat that there is strong inter-sibling aggression in wild Sandhill Crane chicks, occasionally resulting in the death of the second chick. Aggression between crane chicks in all species is well known in captivity (Larue 1981, Derrickson & Carpenter 1987). Walkinshaw (1965a, 1981a), however, points out that the successful rearing of two young together does occur and is brought about by the parents dividing the brood between them ('brood splitting').

Sibling aggression, sometimes resulting in the death of the smaller chick, also has been recorded in the Eurasian Crane (Cramp & Simmons 1980). Brood splitting is believed to be the key to the survival of both young in this species (Cramp & Simmons 1980). Masutomi (1981) reports sibling aggression in the Redcrowned Crane and suggests it may lead to mortality in broods of two young. All the evidence presented above contradicts the statement by Maclean (1991) that there "is no siblicide in any species of crane, as far as is known". Dehao *et al.* (1991) note that siblicide has been alleged as regular in the Blacknecked Crane. Their observations, however, of a brood of two young in this species lead them to conclude that, although some sibling aggression was noted, it was unlikely to result in mortality. Aggression only occurred on the day the second chick hatched and the relationship between the two chicks was harmonious after they left the nest the following day. In the Demoiselle Crane, parents have been observed to split the brood but no fighting was observed between young at any stage in the wild (Winter 1991). Sibling aggression has been seen in wild Blue Crane chicks (Walkinshaw 1963) and was characteristic and intense in young reared in captivity at a bird park ('World of Birds') in Cape Town (W. Mangold pers. comm.).

If brood splitting is necessary for two young to be reared simultaneously, due to sibling aggression, then this aggression militates against a clutch size of more than two eggs and indeed may be the key factor determining clutch size in these birds.

Miller (1973), however, has significantly under-estimated the proportion of two-chick broods in some cranes, including subspecies of the Sandhill Crane other than the Lesser Sandhill Crane, and therefore the frequency with which a fatal outcome to sibling aggression is avoided. Both young produced by the typical two-egg clutch of most of the gruine cranes regularly are reared together successfully (Appendix 1.3). Between 12% and 67% of fledged broods consisted of two young in the seven gruine species examined. In Greater and Florida Sandhill Cranes, 12-44% of fledged broods had two young. Bin & Zuoyi (1991) found that fledged brood sizes of most families of Whitenaped Cranes on their wintering grounds consisted of two young, but do not report full details. Dwyer & Tanner (1992) in their study of Florida Sandhill Cranes, reported that "both members of a brood seldom survived", but do not provide supporting details.

In the Eurasian Crane, fledged brood sizes were similar between years and localities, despite relatively large differences in the proportion of successful breeding pairs between years and localities (Prange & Mewes 1991). Nilsson (1982) and Alonso, Veiga & Alonso (1987), however, found that brood sizes were positively correlated with the relative proportion of successful breeding pairs in this species.

Broods of three young have been recorded regularly for Grey Crowned Cranes, at least in East Africa (Pomeroy 1980, Frame 1982, Mafabi 1991). At least two of these

instances involved recently fledged young, and the role of sibling aggression and brood splitting requires investigation in this species.

Post-fledging dependence period

Young cranes typically remain with their parents for several months, up to a year, after fledging (e.g. Tacha 1988, Alonso, Veiga & Alonso 1987). Even when family units join up with flocks, the young remain in close proximity to their parents, including during migration (Miller & Stephen 1966, Lovvorn & Kirkpatrick 1982b, Layne 1983, Tacha & Vohs 1984). In one study of the Sandhill Crane, 90% of juveniles remained with their parents throughout the sojourn on the wintering grounds and parent-offspring units only disintegrated halfway through the return migration to the breeding grounds (Tacha 1988). Young Whooping Cranes also only leave their parents during the return migration to the breeding grounds (Lingle *et al.* 1991). In the Eurasian Crane, family cohesion gradually decreases on the wintering grounds and juveniles depart for the breeding grounds after adults (Alonso, Veiga & Alonso 1984). Siberian Crane juveniles are reliant on their parents for food virtually throughout the period on the wintering grounds and only learn to find food for themselves during the final weeks before the return migration (Zhiyong & Bin 1991).

Breeding productivity

There are few studies of productivity based on monitoring the success of individual breeding pairs. Bennett & Bennett (1990), Dwyer & Tanner (1992), and Nesbitt (1988, 1992) provide useful reviews of such studies for the Sandhill Crane. It is difficult to compare directly the results of many studies of breeding productivity in cranes, due to differences in methodology, analysis and presentation between them. For example, some of these studies exclude data from nests that failed due to human disturbance (e.g. Walkinshaw 1949), while others include data from such nests (e.g. Bennett & Bennett 1990).

The monitoring of breeding productivity is hampered by several practical difficulties. One problem lies in the interpretation of the status of the individuals occurring in nonbreeding flocks during the breeding season. This segment of the population can be relatively large, and can exceed the number of breeding birds (see under 'Flocking' above). Some of these birds doubtless are below the age when pairing and breeding usually occur (see under 'Mating system and age of first breeding' above). Some, perhaps many, however, probably are old enough to breed but either have not yet paired, or have paired but have not yet established a breeding territory (Nesbitt 1987). They may have previously bred but have lost breeding status due to loss of their mates, or are mated pairs that have bred previously but are not breeding in that particular

breeding season (Konrad 1981). For example, in the Sandhill Crane, breeding females that lost their mates rejoined flocks of nonbreeders, and, in some instances, it was several years before they re-paired and bred again (Nesbitt 1989). In the Eurasian Crane, most nonbreeders in flocks are believed to be adults, including some established pairs that are not breeding in any particular year (Prange & Mewes 1991).

The flocking habits of cranes and the problem that, in most species, only two age classes can be distinguished (first-year birds from those in their second year and older) militate against the identification of these different classes of individuals, without a long-term, extensive marking program.

A further difficulty involves the initial breeding attempts made by cranes. For example, Nesbitt & Wenner (1987) found that in the Sandhill Crane, initial pairings, accompanied by the establishment of a territory, were usually ephemeral, and that nest building and the successful production of eggs and young was uncommon during these liaisons (see under 'Mating system and age of first breeding' above). Similar behaviour has been reported in 'young' pairs of Eurasian Cranes (Bylin 1980). Nesbitt & Wenner (1987) report that pair bonds in Sandhill Cranes only become permanent after successful breeding. The extent to which breeding attempts by novice pairs should be included when assessing breeding productivity is debatable. It is likely that such breeding attempts frequently are overlooked. For example, the low nesting success found by Nesbitt (1988) for the Sandhill Crane, relative to other studies of this species, has been attributed to the intensity of his study, which resulted in the location and inclusion of breeding attempts by novice pairs, which would have been overlooked in other studies (Dwyer & Tanner 1992). Assessment of productivity is perhaps best restricted to established breeding pairs, with a history of at least one successful breeding attempt.

The occurrence of repeat breeding attempts (see under 'Repeat clutches' above) after initial failure in the same season further confounds measures of annual breeding productivity (e.g. Dwyer & Tanner 1992), unless the birds monitored are individually marked. Repeat attempts can result in the under-estimation of annual breeding productivity. For example, it is not possible to calculate the mean number of young reared/pair/annum from the data presented by Bennett & Bennett (1990), due to the high proportion of repeat attempts.

The mobility of the young can make it difficult to determine whether the eggs in a nest hatched or not. An empty nest may have failed at the egg stage or the young may have left the nest. This mobility of chicks during the fledgling period also can make it problematic to monitor their survival during this time. The characteristic measure of breeding success, number of chicks 'fledged', has little meaning in cranes, which are ground-dwelling and have offspring dependence periods that extend far beyond the age of first flying in the young (see under 'Post-fledging dependence period' above).

Measurement of chick survival to independence requires the monitoring of young until virtually the end of their first year.

Despite the problems outlined above, many studies provide information about breeding productivity based on some measure of breeding success, as discussed below. The relevance of age of first breeding, clutch and brood sizes, and repeat clutches to breeding productivity will not be discussed in detail, as these have already been mentioned. The data on the Grey Crowned Crane in East Africa and the Wattled Crane presented in several of the sections below are biased by the protracted breeding seasons of these species (Irwin 1981, Konrad 1981, Pomeroy 1987, Tarboton, Barnes & Johnson 1987). Some pairs would have bred outside the periods when many of the assessments of breeding status and success were made.

Proportion of pairs attempting to breed each year

This is one of the most poorly-known aspects of breeding ecology, largely due to non-breeding pairs frequently joining flocks and therefore being overlooked (Konrad 1981, Prange & Mewes 1991). As most cranes are dependent on wetlands for breeding and the extent of these habitats frequently fluctuates according to local rainfall conditions, it can be expected that some pairs will be precluded from breeding at sites previously used by them, and that these birds will join flocks when drought conditions prevail (e.g. Kuyt 1981, Tarboton, Barnes & Johnson 1987). Wetland habitats are subject to anthropogenic disturbance (e.g. Archibald *et al.* 1981) and some pairs may be forced to abandon their territories and join flocks when their breeding sites are destroyed (Tarboton, Barnes & Johnson 1987).

The proportion of pairs in several crane species that do not attempt to breed every year is presented in Appendix 1.4. The information presented for the Wattled Crane comes from the Kafue Flats in Zambia, where the proportion of pairs attempting to breed annually fluctuates widely, depending on the flooding of the wetland system (Douthwaite 1974). In normal years, a maximum of 40% of pairs attempts to breed, falling to only 3% in years of unfavourable flooding. Concerning the data for the Florida Sandhill Crane, Layne (1983) ignored any pairs that were in flocks, which results in an underestimation of the proportion of pairs not attempting to breed. He also cautioned that he was unable to identify the proportion of novice pairs in his sample.

Hatching success

Hatching success can be presented either as the success of each individual egg in each clutch monitored (e.g. Kuyt 1981), or can be defined as a nest in which at least one egg hatched (e.g. Dywer & Tanner 1992). The latter is more easily and reliably determined. Johnsgard (1983) provides a brief review of hatching success in cranes.

More recent studies providing and reviewing hatching success data on Sandhill Cranes include Nesbitt (1988), Bennett & Bennett (1990) and Dywer & Tanner (1992). Appendix 1.5 summarizes data from all the studies cited by these authors and additional information not mentioned by them. The data reproduced in Johnsgard's (1983) review contains some omissions and mistakes, when compared with the original publications cited, and these have been amended in Appendix 1.5.

Hatching success would appear relatively high in cranes (Appendix 1.5). Recent studies (Nesbitt 1988, Dwyer & Tanner 1992), however, suggest that traditional methods of determining hatching success in cranes (intermittent nest visits) may significantly over-estimate this measure of breeding success. Nesbitt (1988) found hatching success rates of only 39% and 48%, for eggs and nests respectively, in the Florida Sandhill Crane, and attributed this to the intensity of his study, which located and included novice pairs that frequently abandoned clutches soon after laying them. Dywer & Tanner (1992) were the first to employ the Mayfield method (Mayfield 1961, 1975) in assessing breeding success in cranes. They found a hatching success rate (per nest) of 59% in Florida Sandhill Cranes, whereas use of the traditional method would have given a figure of 68%. The Mayfield method is preferable, as it compensates for nests which failed soon after initiation and before being discovered.

Brood success

Brood success (Appendix 1.6), similar to hatching success, can be expressed either as the proportion of individual young fledged relative to the number of eggs hatched (e.g. Masatomi 1981), or as the proportion of broods in which at least one young fledged (e.g. Bennett & Bennett 1990). Relevant to the data on the Whooping Crane (appendix 1.6), which almost exclusively rears a single chick per breeding attempt (see under 'Brood sizes' above), the proportion of young fledged equals the proportion of broods that were successful.

Layne (1983) showed that there was a decrease in mean brood size in Florida Sandhill Cranes, due to the attrition of individual young, during the course of the fledgling period, with a mean of 1,71 young/brood (n=17 broods) during the first month, 1,62 young/brood (n=26 broods) 2-3 months of age, and 1,44 young/brood (n=142 broods) after three months. Florida Sandhill Cranes fledge at about three months old. This decrease in mean brood size does not accurately measure brood success, however, as loss of entire broods is overlooked.

Even less information is available on survival during the post-fledging to independence period. About 25% of Whooping Crane chicks survive from hatching to arrival on the wintering grounds in Texas (Erickson & Derrickson 1981), with 35% dying during the fledgling period and 40% perishing between fledging and completing

the southward migration. In the Lesser Sandhill Crane, about 80% of young survive between fledging and arrival on the wintering grounds (Tacha *et al.* 1989). Nesbitt (1992) reports that 82% of young Florida Sandhill Cranes survive from fledging to independence (248-321 days old). The probability of surviving from hatching to independence was 57% in his study. In the Eurasian (Alonso, Veiga & Alonso 1987) and Siberian (Zhigang *et al.* 1991) Cranes, age ratio data (see under 'Percentage of juveniles in other cranes' below) suggest that 6,7% and 22,2% respectively of juveniles die during the winter period. These estimates, however, are based on the assumption that adult mortality during this period is zero, which probably is unrealistic.

Proportion of pairs with fledged young

Another measure of breeding success is the proportion of pairs with and without fledged young in the post-breeding period. This information is relatively easily obtained. Its accuracy, however, again is compromised by the problem of some pairs without young joining flocks, especially as pairs with young avoid flocks (Miller & Hatfield 1974, Tacha & Vohs 1984, Alonso, Veiga & Alonso 1987, Bishop 1988). This would result in a tendency to over-estimate the success of breeding pairs. In addition, it can be difficult to identify the members of different pairs and their offspring in flocks (Layne 1983, pers. obs), which presents the practical problem of assessing brood size, i.e. one pair with two chicks or two pairs with one chick?

Several studies present data on the proportion of pairs with fledged young, relative to the total number of pairs (Appendix 1.7).

Number of young reared/pair/annum

The number of young reared per pair per annum (Appendix 1.8) probably is the most widely used measure of breeding success in avian studies. It can be expressed relative to either the total number of mated pairs or the number of breeding pairs which lay eggs. The former approach is preferable for assessing overall population breeding productivity. Data on the proportion of pairs with young in the post-breeding period, coupled with knowledge of mean brood size (Appendix 1.7), have been translated into a measure of young/pair/annum in Appendix 1.8 in some cases. The information on the Whooping Crane is based on that presented in Johnsgard (1983), and assumes that repeat nesting attempts are rare and that only one young is reared per successful attempt (Novakowski 1966, Kuyt 1981). In the Florida Sandhill Crane, the data presented from Nesbitt (1992) is based on his finding that mean individual breeding productivity was 0,35 young/adult/annum for all adults in the population (n=133 adults during 574 crane breeding years). The same calculation restricted to adults that had bred successfully at least once gives a figure of 0,51 young/adult/annum.

Percentage of juveniles in the total population

The proportion of juvenile cranes in the population, as assessed during the post-breeding period, has been widely used to assess the productivity of several crane populations. Information on this measure of recruitment to the total population is relatively easily collected and need not be negatively affected by the flocking habits of cranes. It is extremely valuable in conservation and management assessments, especially as it provides extensive sample sizes of population-wide productivity and measures survival of young well beyond the fledgling period. Healthy populations of cranes should have about 10-15% juveniles in the post-breeding period (Archibald *et al.* 1981).

Extensive information in this regard has been collected for many crane species, especially the Sandhill Crane (Appendices 1.9 and 1.10). In compiling Appendices 1.9 and 1.10, data from different years have been treated separately in the calculations.

Percentage of juveniles in Sandhill Cranes

Recruitment rates of 13-14% characterized increasing populations of Rocky Mountain Greater Sandhill Cranes (Drewein 1973, in Bennett & Bennett 1990), while rates of 8-10% characterized stable populations of Central Valley Greater Sandhill Cranes (Littlefield & Ryder 1968, in Bennett & Bennett 1990) . The apparent decrease in the proportion of juveniles (from 19,4% in 1952-58 to 7,7% in 1984-86) in Eastern Greater Sandhill Cranes during 1952-1986, has been attributed to the stabilization of the increase in this taxon's numbers during this time (Lovvorn & Kirkpatrick 1982b). Working on this taxon after the stabilization of the increase, Urbanek *et al.* (1991) found that a juvenile percentage of 4,8% characterized a year of poor breeding success, while a percentage of 9,9% characterized a year of high breeding success. A stable population of Florida Sandhill Cranes had 11,1% juveniles (Nesbitt 1992). During the period when most of these data were collected, the Eastern and Rocky Mountain populations of the Greater Sandhill Crane, and the Lesser and Canadian Sandhill Cranes were believed to be increasing, and the Central Valley population of the Greater Sandhill Crane and the Florida Sandhill Crane were believed to be stable (Drewein & Lewis 1987). The difference in annual recruitment between the Lesser and Greater/Canadian Sandhill Cranes may be due to the latter breeding at an earlier age than the former (Tacha & Vohs 1984, Tacha *et al.* 1984, 1986, 1989). Differences in mean brood size, however, between the Lesser Sandhill Crane and other sub-species (Appendix 1.3), also could be involved.

Percentage of juveniles in other crane species

Several of the species, or populations of species, in Appendix 1.10 have characteristics worth mentioning, relevant to the interpretation of age ratio data.

The relatively low percentages of juvenile Eurasian Cranes counted in Sweden by Swanberg (1981) may be due to age related differences in migration patterns in some years. Prange & Mewes (1991) suggest that the figures of 14-16% juveniles in Central Europe represents an increasing population, 12,3% in Scandanavia a stable population, and 9,0% in Finland a decreasing population. The Scandanavian population, however, also may have been increasing during this period (Bylin 1987).

The data for the Hooded Crane in Izumi, Japan are anomalous. During the period 1968-72, the percentage of juveniles decreased in the following manner: 1968-20,0%, 1969-15,0%, 1970-11,7%, 1971-11,0%, 1972-2,0%. The author provides no explanation for this dramatic and monotonic decrease. The data presented for this species in Yashiro, Japan are based on a remnant wintering population.

The information on the Whooping Crane cannot be regarded as representative of the natural situation in cranes, as it covers a period during which the population recovered from virtual extirpation (18 individuals) to 72 individuals. It is of interest to note that the percentage of juveniles decreased during this period of population increase, possibly associated with saturation of the available breeding habitat (Johnsgard 1983). The data for the Redcrowned Crane in Japan also are from a rapidly increasing population. In this population the percentage of juveniles remained relatively high (12,7%) and constant during the period of increase, although there was an apparent reduction in the percentage of juveniles (from about 13-14% to about 12%) during the latter stages of the increase, due to saturation of the breeding habitat (Archibald 1987). The data on the Siberian Crane from India is for the remnant, and still decreasing, western population. The percentage of juveniles remained relatively high (14,3%) and constant during this period of steep population decrease (Sauey 1987).

The data from White (1987) on the Australian Crane are not directly comparable with those for the other species. He states that his figure of 10% juveniles in the population refers to a combination of both first- and second-year birds. Both age classes can be differentiated from adults in this species. The same may also apply to the data from Blackman (1971) for this species, and might explain the relatively high proportion of 'juveniles' recorded by him. Similarly, the surprisingly high percentages of juveniles recorded for the other two members of the 'Antigone' group of gruine cranes (see under 'Phylogenetic relationships within the cranes' above), the Sarus and Whitenaped Cranes, may also be due to both first- and second-year young being counted. The relatively high proportion of young birds counted by Kemin & Zhongqin (1991) for the Redcrowned Crane may also include some birds older than first-years, as they use the

term 'sub-adults' when reporting their results. Second-year Siberian Cranes, and even third-year immatures, are distinguishable from adults (Flint & Kistchinski 1981) and therefore some of the results presented for this species in Appendix 1.10 also may be biased.

Differences between the numbers of juveniles counted during the autumn and spring migrations have been found in the Eurasian (Alonso, Veiga & Alonso 1987) and Redcrowned (Zhigang *et al.* 1991) Cranes. In the former there was a decrease of 6,7% in the number of juveniles between these two periods, and in the latter a decrease of 22,2%.

Four age classes are recognizable in the Siberian Crane, and Flint & Kistchinski (1981) provide one of the few analyses of age structures in crane populations. On the breeding grounds, they found that 7,3% comprised first-year birds, 17,0% second-years, 34,1% third-years, and 41,6% fourth-year and older birds in this species (n=41 birds aged). The explanation offered for the obvious discrepancy in these figures is that some young birds do not return to the breeding grounds until they are mature. They also suggest that, as birds of three years old can breed, the total proportion of sexually immature cranes in the population is about 25%, but that this figure also is subject to the same bias. Zhigang *et al.* (1991), however, based on observations at a migratory stopover site, suggest that 24% comprised first-year birds, 16% sub-adults, and 60% paired adults in this species (n=100 birds aged).

Based on observations of migrating cranes, Williams *et al.* (1991) recorded 84,2% adults, 15,5% juveniles and 0,3% sub-adults in Eurasian Cranes (n=871 birds aged), and 76,7% adults, 21,8% juveniles and 1,5% sub-adults in Redcrowned Cranes (n=206 birds aged).

Problems with percentages of juveniles data

The collection of data on the proportion of juveniles in biological populations and its interpretation when assessing productivity must be made with care (Caughley 1974), as the results are influenced by several confounding variables. Relevant to cranes, these include differential habitat use (Buller 1979, Lovvorn & Kirkpatrick 1982b, Alonso, Veiga & Alonso 1987), timing of roosting and choice of roosts (Lovvorn & Kirkpatrick 1982b), distance of the birds from roosts (Alonso, Veiga & Alonso 1987), migration routes (Swanberg 1981), and the timing of migration by family units (Miller & Hatfield 1974, Swanberg 1981, Carlisle & Tacha 1983, Tacha & Vohs 1984, Tacha, Jorgenson & Taylor 1985) compared to the balance of the population, and avoidance of large flocks by family groups (Miller & Hatfield 1974, Tacha & Vohs 1984, Alonso, Veiga & Alonso 1987, Bishop 1988). Age ratios also can differ between locations in the nonbreeding range of migratory populations of Eurasian (Alonso, Veiga & Alonso 1987)

and Sandhill (Tacha & Vohs 1984) Cranes. In the former, fewer juveniles were found at staging areas and irregularly-used wintering sites compared to typical wintering sites. The data presented in Appendices 1.9 and 1.10 show variation between percentages of juveniles counted in breeding areas, during migration at stopover and staging areas, and on the wintering grounds for several species. Counts of juveniles also differ between autumn and spring at stopover sites (Alonso, Veiga & Alonso 1987, Zhigang *et al.* 1991). The inclusion of immatures older than one year in counts of 'juveniles', in those species where more than two age classes can be discerned, is an additional problem (see under 'Percentage of juveniles in other cranes' above).

Estimates of proportions of juveniles in Sandhill Cranes reported by Layne (1983) are exaggerated, as the latter only counted family groups and not unsuccessful breeders and nonbreeders (Bennett & Bennett 1990). The data from Layne's study therefore are not directly comparable with most other studies of productivity based on counts of adult:juvenile ratios, and are excluded here. Estimates of annual recruitment based on age ratios of migrating Sandhill Cranes at one staging area in the Central Flyway were unreliable, due to extensive overall and age-related variation in migration phenology, both within and between years (Carlisle & Tacha 1983). The data from Miller & Hatfield (1974) in Appendix 1.9 probably are unreliable. They based their counts on cranes seen in flight and Tacha & Vohs (1984) show that accurate aging is not possible for flying Sandhill Cranes. In addition, their study site was a staging area in the Central Flyway and therefore probably subject to the same migration phenology problems found by Carlisle & Tacha (1983). Indeed, Miller & Hatfield (1974) report differences in age ratios related to time periods and suggest that their counts in one year were prior to the arrival of most of the population. They suggest that a figure of 6,5% found in another year, when the population had peaked, probably was more accurate.

Counts of the proportion of juveniles are affected by the proportion of nonbreeders in the population (Lovvorn & Kirkpatrick 1982b). Therefore the proportion of juveniles may change, not only in response to breeding success, but also due to changes in the numbers of nonbreeders present. For example, an increase in the proportion of juveniles may be due to mortality of, or emigration by, nonbreeders, while a decrease may be due to relatively large numbers of nonbreeders, brought about by immigration or high productivity in previous breeding seasons (Lovvorn & Kirkpatrick 1982b).

1.4) *Conservation status*

International Red Data Book status of cranes

Cranes are among the most threatened avian taxa. Seven of the world's fifteen species are listed in the International Council for Bird Preservation's (ICBP, now Birdlife International) Checklist of Threatened Birds (Collar & Andrew 1988). These

are the Hooded, Whooping, Blacknecked, Redcrowned, Whitenaped, Wattled, and Siberian Cranes. The conservation saga of the Whooping Crane is renowned (see Erickson & Derrickson 1981 for a useful review) and has become a symbol of conservation efforts to preserve threatened species (Binkley & Miller 1980).

Conservation status of African cranes

The Wattled Crane is the only African crane listed in the ICBP Checklist. The African Red Data Book of the ICBP/IUCN (International Union for the Conservation of Nature and Natural Resources) lists this species as 'Of Special Concern' (Collar & Stuart 1985). The South African Red Data Book (Brooke 1984) categorizes the Wattled Crane as 'Endangered'; one of only five bird species in the region that are considered in imminent danger of local extinction. The conservation status of this species in South Africa is discussed in detail by Geldenhuys (1984), Tarboton (1984), Vernon & Boshoff 1986, Tarboton, Barnes & Johnson (1987), Brooke & Vernon (1988), and Johnson & Barnes (1991).

The other three breeding cranes found in sub-Saharan Africa, the Black and Grey Crowned Cranes and the Blue Crane, were not considered as threatened by any of these Red Data Books. Recently, however, concern has been expressed as to the conservation status of the Black Crowned Crane, especially in West Africa (Urban 1987). The Grey Crowned Crane cannot, as yet, be considered as globally threatened and has a total population of at least 100 000 individuals (Urban 1988). The South Africa breeding population, however, probably does not exceed 1000 pairs (Geldenhuys 1984, Johnson & Barnes 1986, Johnson 1992a, Tarboton 1992a, Vernon 1992). These latter authors all claim that the species is decreasing locally, due to wetland degradation and poisoning. It should therefore be considered as a candidate for inclusion as a Red Data Book species in South Africa.

Threats to cranes

The major threats to cranes worldwide are habitat destruction and persecution (Archibald *et al.* 1981). Habitat destruction usually comes in the form of degradation of wetlands and surrounding areas, and can include the impact of commercial afforestation. Afforestation has been implicated as a threat to the Mississippi Sandhill Crane, a critically endangered subspecies of this crane (Valentine 1987), to the Wattled Crane in Zimbabwe, Malawi and the Transvaal (West 1977, in Konrad 1981, Tarboton 1984), and to the Blue Crane (Johnson 1992a). Persecution is usually motivated by crop damage and can be of particular concern when poisons are used to kill large numbers of cranes. The Australian Crane, for example, has suffered major mortalities due to poisoning to protect crops (White 1987). Mortality due to poisoning by farmers also has

been reported for the Grey Crowned, Eurasian, Blacknecked, Demoiselle, Blue and Wattled Cranes (van Ee 1981, Ledger 1985, 1988, Bennett 1986, Johnson & Barnes 1986, Fuzhang & Wenning 1987, Tyson 1987, Vernon 1987, Khachar *et al.* 1991, Urquhart 1991, Youhui 1991, Filmer & Holtshausen 1992, Johnson 1992a, 1992b, Stretton 1992, Tarboton 1992a, Vernon *et al.* 1992).

Collisions with overhead transmission lines also are proving to be a significant cause of direct mortality in many species. In the Redcrowned Crane in Japan, 71% (n=245) of known mortalities were due to such collisions before markers were placed on the relevant lines rendering them more visible to flying cranes (Akiyama 1981). This was calculated as 2,1% of all mortalities in adults and 13,1% in juveniles (Archibald 1987). This source of unnatural mortality has been identified as the key factor that retarded the recovery of this species in Japan, until ameliorative measures were implemented (Masatomi 1991). A similar problem exists in Korea (Kyu & Oesting 1981). This source of mortality also has been recorded and considered as potentially serious in the Whooping (Erickson & Derrickson 1981, Kuyt 1987) Australian (White 1987, Goldstraw & Du Guesclin 1991), and Sandhill (Walkinshaw 1956, Tacha *et al.* 1979 in Johnsgard 1983, Windingstad 1988) Cranes. One study of the Eurasian Crane found that eight of 17 adults found dead were killed by colliding with overhead lines (Neumann 1987). In South Africa, at least three Wattled Cranes have died in this way (Berruti 1990, Johnson 1991). Fences also can present hazards to cranes, and mortalities caused by these structures have been recorded in at least Whooping, Australian, Blue and Sandhill Cranes (White 1987, Allen 1990, Filmer & Holtshausen 1992).

Simulation models devised for the management of Sandhill Cranes (Miller *et al.* 1972, Miller & Bodkin 1974) have highlighted the vulnerability of populations of this species to unnatural mortality of adult birds. This vulnerability is due to the species' low reproductive potential. The purpose of their studies was to examine the potential impact of hunting on this crane, but can be extrapolated to other forms of unnatural mortality, such as poisoning and collisions with overhead lines, and to other species of cranes, all of which have similarly low reproductive potentials. A similar model has been produced for the Eurasian Crane, which identifies the potential importance of density-dependent factors, i.e increased reproductive success at reduced densities, in mitigating the effects of increased unnatural mortality of adult cranes (Alonso *et al.* 1991). Unfortunately no data are available on density-dependent population parameters in cranes.

Archibald (1987), working on the Redcrowned Crane, highlights the importance of monitoring breeding success and recruitment in addition to population size. Pairs of

long-lived cranes may inhabit areas long after their breeding habitat has been destroyed and therefore a population decrease may become apparent only several years later.

Adaptability of cranes to anthropogenic change

The discussion presented in this chapter repeatedly illustrates the adaptability of cranes to man-modified conditions. This includes their ubiquitous use of agricultural foods and foraging habitats, and their ability to adjust their patterns of movements, migrations, and roosting in response to man-made alterations of natural environments. Even when breeding, many species show surprising tolerance in nesting close to human activities, e.g. Sandhill (Dwyer & Tanner 1992) and Redcrowned (Archibald 1987) Cranes. Demoiselle Cranes will even nest in agricultural fields (Kovshar 1987). Other examples include the Eurasian Crane in Sweden and Poland, which has undergone a dramatic increase recently, due to its adapting to breeding near to human activity (Bylin 1987, Dobrowolski & Halba 1987). The Sarus Crane in India (Archibald *et al.* 1981), and the Grey Crowned Crane in Transkei, South Africa (Quicklberge 1989) and in East Africa (Pomeroy 1987) both benefit from co-existence with tolerant local peoples and despite the density of the human populations in these areas. It has been shown (Masatomi 1991) that even the problem of collisions with overhead lines can be solved by rendering these more visible to flying cranes using markers.

Captive breeding of cranes

The contribution of captive breeding to the conservation of cranes has received much attention, largely through the efforts of the International Crane Foundation, and large numbers of most species breed regularly in captivity (Mirande 1991). A list of the numbers of Grey Crowned, Blue and Wattled Cranes held in captivity in southern Africa has been compiled (Allan 1985).

An integrated approach to crane conservation research

A useful outline of the integrated research program needed to compile a strategy for the efficient and successful management and conservation of cranes has been produced, using the Sandhill Crane as a model (Tacha *et al.* 1987). It includes a brief summary of the relevant biological data that need to be gathered. These include details of population size, age and sex distributions, reproductive strategies, recruitment, mortality, migration routes, seasonal distribution patterns, habitat use and feeding ecology, a behavioural repertoire and time budgets, energetics, diseases and parasites, and social organization. They stress that all these aspects must be covered to ensure that any potentially problematic areas are identified. They also insist that these aspects must be studied throughout the annual cycle and simultaneously, rather than piecemeal at different times or locations.

The difficulties in successfully achieving this goal are admitted by these authors, who confess that scientists "have studied midcontinent Sandhill Cranes for years, but still cannot identify population trends". They recommend that "determining with precision the status and trends of populations for all species of cranes should be a research priority".

Archibald *et al.* (1981) provide a discussion of practical methods that can be employed in crane conservation. These include the reinforcement of traditional, and cultivation of new, human values, protective legislation and its enforcement, winter feeding (Koga 1981, Ohsako 1987, Swanberg 1987), habitat protection and enhancement, and re-stocking programs.

Potentially significant threats that have as yet received little attention are the long-term effects of very small population sizes, and population and habitat fragmentation. Another poorly-researched field is the impact of predators on crane populations. It is likely that the natural relationship between cranes and their predators has been modified by anthropogenic changes. The intensive control of mammalian predators in small stock farming regions may be to the benefit of cranes, especially during the breeding cycle.

Appendix 1.1 The proportion of cranes that are nonbreeders relative to the total population.

Species	Percentage nonbreeders	Source
Black Crowned	63%	Walkinshaw (1981b)
Grey Crowned	17% (Serengeti)	Frame (1982)
	82% (Ngorongoro)	Frame (1982)
	50% (East Africa)	Pomeroy (1987)
	48% (Uganda)	Mafabi (1991)
	41% (Zim./Zam./Natal)	Walkinshaw (1964)
	60% (Transvaal)	Tarboton (1992a)
Eurasian	51%	Prange & Mewes (1991)
Whooping	50%	Kuyt (1981)
Blacknecked	52%	Dehao *et al.* (1991)
Redcrowned	66%	Mingyu *et al.* (1991)
Sarus	31%	Gole (1987)
Blue	72%	Geldenhuys (1984)
Wattled	59% (Kafue)	Douthwaite (1974)
	58% (Kafue)	Howard (1989)
	81% (Zambia)	Howard & Aspinwall (1984)
	47% (Zimbabwe)	Mundy *et al.* (1984)
	31% (Zambia & Botswana)	Konrad (1981)
	10% (Transvaal)	Tarboton, Barnes & Johnson (1987)
	25% (Natal)	Johnson & Barnes (1991)
Siberian	62% (Siberia)	Flint & Kistchinski (1981)
	40% (China)	Zhigang *et al.* (1991)
Lesser Sandhill	48%	Tacha *et al.* 1989
Greater Sandhill	40% (Michigan)	Walkinshaw (1955)
	53% (Minnesota)	Grewe (1977, in Walkinshaw 1981a)
	79% (Manitoba)	Melvin *et al.* (1990)
Florida Sandhill	26%	Bennett (1989a)

Appendix 1.2 Clutch sizes in cranes.

Species	1 egg	2 eggs	3 eggs	4 eggs	Mean clutch size	n=	Source
Black	-	3	14	-	2,47	17	Walkinshaw (1973)
Crowned	-	1	4	-	2,80	5	Walkinshaw (1981b)
Grey Crowned							
Kenya/Uganda	-	-	-	-	2,56	41	Pomeroy (1980)
Zim/Zam./Mal.	-	-	-	-	2,33	28	Urban *et al.* (1986)
Zim./Zam.	4	3	10	-	2,35	17	Walkinshaw (1964)
Sthn Afr.	-	-	-	-	2,44	34	Urban *et al.* (1986)
Sthn Afr.	-	-	-	-	2,6	51	Maclean (1993)
South Africa	3	10	16	5	2,67	34	Walkinshaw (1973)
Transvaal	7	15	21	3	2,87	39	Tarboton (1992a)
Natal	-	-	-	-	2,93	16	Urban *et al.* (1986)
E. Cape	-	19	15	1	2,49	35	Vernon *et al.* (1992)
Eurasian	1	15	1	-	2,00	17	Glutz (1973, in Johnsgard 1983)
	2	17	-	-	1,89	19	Glutz (1973, in Johnsgard 1983)
	-	-	-	-	1,97	263	Prange & Mewes (1991)
Whooping	17	220	3	-	1,94	240	Kuyt (1981)
Blacknecked	3	7	-	-	1,70	10	Dehao (1987)
	1	3	-	-	1,75	4	Dehao *et al.* (1991)
Redcrowned	-	-	-	-	1,83	52	Masatomi (1981)
	1	4	-	-	1,80	5	Viniter (1981)
	4	13	1	-	1,83	18	Ma (1981)
Sarus	4	126	2	-	1.99	132	Walkinshaw (1973)
Australian	6	20	1	-	1,82	27	Walkinshaw (1973)
	10	21	-	-	1,68*	31	White (1987)
Whitenaped	1	22	-	-	1,96	23	Liying *et al.* (1991)
Demoiselle	1	7	-	-	1,88	8	Glutz (1973, in Johnsgard 1983)
	-	7	-	-	2,00	7	Xueming & Junchang (1991)
	1	28	-	-	1,97*	29	Winter (1991)
Blue	7	53	1	-	1,90	61	Walkinshaw (1973)
	-	-	-	-	1,8	150	Maclean (1993)
	-	8	-	-	2,0	8	Brown (1992a)
	-	17	-	-	2,0	17	Vernon *et al.* (1992)

Appendix 1.2 (cont.)

Species	1 egg	2 eggs	3 eggs	4 eggs	Mean clutch size	n=	Source
Wattled							
Sthn Afr.	38	57	-	-	1,60	95	Konrad (1981)
Zambia	12	16	-	-	1,57	28	Benson & Pitman (1964)
Zimbabwe	-	5	-	-	2,00	5	West (1963)
Zimbabwe	4	2	-	-	1,33	6	Mundy *et al.* (1984)
Zimbabwe	10	11	-	-	1,52	21	Urban *et al.* (1986)
Transvaal	31	7	-	-	1,18	38	Tarboton, Barnes & Johnson (1987)
Natal	43	27	-	-	1,39	70	Tarboton, Barnes & Johnson (1987)
Siberian	-	-	-	-	1,75	12	Flint & Sorokin (1981)
Lesser	17	54	-	-	1,76	71	Boise (1976, in Walkinshaw 1981a)
Sandhill	11	76	-	-	1,87	87	Walkinshaw (1981a)
Canadian							
Sandhill	5	48	-	-	1,91	53	Walkinshaw (1981a)
Greater	9	99	-	-	1,92	108	Littlefield & Ryder (1968, in Johnsgard 1983)
Sandhill	24	310	3	-	1,94	337	Drewein (1973, in Johnsgard 1983)
	-	-	-	-	1,91	-	Bennett (1978, in Nesbitt 1988)
	17	275	1	-	1,95	293	Walkinshaw (1981a)
	7	37	2	-	1,89	46	Melvin *et al.* (1990)
Florida	10	54	-	-	1,84	64	Thompson (1970)
Sandhill	13	181	-	-	1,94	194	Walkinshaw (1973, 1982, in Johnsgard 1983)
	28	71	-	-	1,72	99	Nesbitt (1988)
	22	165	-	-	1,88	187	Bennett & Bennett (1990)
	18	75	-	-	1,81	93	Dwyer & Tanner (1992)
Mississipi	7	28	1	-	1,83	36	Walkinshaw (1981a)
Sandhill	-	-	-	-	1,86	79	Valentine (1982, in Johnsgard 1983)
Cuban							
Sandhill	-	10	-	-	2,00	10	Walkinshaw (1973)

* - all complete clutches

Appendix 1.3 Brood sizes in cranes (excluding the Whooping, Wattled and Siberian Cranes).

Species	Mean brood size	% 2Y broods	n= broods	Source
Grey Crowned				
E. Afr.	2,1*		35	Pomeroy (1987) (pre-fledging)
E. Afr.	1,7+	70%	39	Pomeroy (1987) (at fledging)
E. Afr.	1,5+	50%	32	Pomeroy (1987) (post-fledging)
E. Afr.	1,6*	60%	9	Frame (1982)
E. Afr.	2,1*		12	Mafabi (1991)
E. Afr.	2,3+		3	Mafabi (1991)
S. Afr.	1,7*	50%	13	Filmer & Holtshausen (1992)
S. Afr.	1,55*	55%	29	Tarboton (1992a)
Eurasian	1,18+	18%	887	Fernandez-Cruz (1981)
	1,25+	25%	-	Swanberg (1981)
	1,34+	34%	41	Nilsson (1982)
	1,33+	33%	424	Alonso, Veiga & Alonso (1987)
	1,24+	24%	33	Bylin (1987)
	1,89*	89%	*ca* 90	Prange & Mewes (1991)
	1,37+	37%	173	Prange & Mewes (1991)
	1,42+	42%	1164	Prange & Mewes (1991)
Hooded	1,48+	48%	-	Nishida (1981)
	1,29+	29%	34	Chishan & Xiaolun (1987)
Sarus	1,25*	25%	4	Gole (1987)
Australian	1,23*	23%	43	White (1987)
Whitenaped	1,27+	27%	-	Nishida (1981)
Demoiselle	1,50*&+	50%	14	Kovshar (1987)
	1,50*	50%	14	Winter (1991)
	1,67+	67%	9	Winter (1991)
Blue	1,58*&+	58%	12	Brown (1992a)
	1,50*	50%	92	Filmer & Holtshausen (1992)
Lesser	1,00+	0%	623	Miller (1973)
Sandhill	1,00+	0%	-	Tacha *et al.* (1989)
Greater	1,31+	31%	324	Walkinshaw (1973)
Sandhill	1,35+	35%	372	Drewien (1973, in Johnsgard 1983)
	1,24+	24%	282	Drewien & Bizeau (1974, in Johnsgard 1983)
	1,20+	20%	134	Littlefield (1976, in Johnsgard 1983)
	1,36+	36%	-	Bennett (1978, in Bennett & Bennett 1990)
	1,19+	19%	-	Lovvorn & Kirkpatrick (1982b)

Appendix 1.3 (cont.)

Species	Mean brood size	% 2Y broods	n= broods	Source
Florida Sandhill	1,11	11%	27	Walkinshaw (1976, in Johnsgard 1983)
	1,65*	65%	43	Layne (1983)
	1,44+	44%	142	Layne (1983)
	1,25+	25%	-	Bishop (1988, in Bennett & Bennett 1990)
	1,12+	12%	34	Bennett & Bennett (1990)

* - fledgling stage
+ - at or post-fledgling stage

Appendix 1.4 The proportion of pairs in various crane populations that do not attempt to breed every year.

Species	% pairs not br.	Source
Eurasian	14%	Neumann (1987)
Blacknecked	46%	Dehao *et al.* (1991)
Sarus	50%	Gole (1987)
Wattled		
Kafue	60-97%	Douthwaite (1974)
Zimbabwe	59%	Mundy *et al.* (1984)
Natal	41%	Johnson & Barnes (1991)
Siberian	40%	Flint & Sorokin (1981)
Florida Sandhill	44%	Layne (1983)

Appendix 1.5 Hatching success in cranes, presented as the percentage of individual eggs hatched (% eggs hatched) and as the percentage of nests in which at least one egg hatched (% nests hatched).

Species	% eggs hatched	% nests hatched	Source
Grey Crowned	56%	-	Pomeroy (1980)
Eurasian	-	73%	Glutz (1973, in Johnsgard 1983)
	74%	-	Glutz (1973, in Johnsgard 1983)
	-	63%	Glutz (1973, in Johnsgard 1983)
	-	70,7%	Prange & Mewes (1991)
Whooping	79%	-	Kuyt (1981)
Redcrowned	79%	74%	Masatomi (1981)
	93%	-	Ma (1981)
Demoiselle	73%	82%	Winter (1991)
Blue	89%	93%	Walkinshaw (1963)
Wattled	-	55%	Johnson & Barnes (1991)
Lesser Sandhill	64%	67%	Boise (1976, in Johnsgard 1983)
Greater Sandhill	67%	75%	Walkinshaw (1949)
	-	78%	Drewien (1973, in Johnsgard 1983)
	-	44%	Littlefield (1976, in Johnsgard 1983)
	-	84%	Bennett (1978, in Bennett & Bennett 1990)
	73%	77%	Hoffman (1979, in Johnsgard 1983)
	77%	82%	Walkinshaw (1981a)
Florida Sandhill	70%	88%	Thompson (1970)
	77%	74%	Walkinshaw (1981a)
	39%	48%	Nesbitt (1988)
	-	57%	Bennett & Bennett (1990)
	-	59%	Dwyer & Tanner (1992)
Mississippi Sandhill	-	64%	Valentine (1982)

Appendix 1.6 Brood success of cranes, presented as the percentage of individual young fledged (% Y fledg.) from eggs hatched, and as the percentage of nests in which least one young fledged (% nests fledg.) for nests in which eggs hatched.

Species	% Y fledg.	% nests fledg.	Source
Grey	60%	-	Pomeroy (1980)
Crowned	28%	-	Mafabi (1991)
Eurasian	73%	-	Prange & Mewes (1991)
Redcrowned	56%	-	Masutomi (1981)
	60-70%	-	Viniter (1981)
Whooping	65%	-	Novakowski (1966), Kuyt (1981) (both in Johnsgard 1983)
Demoiselle	63%	64%	Winter (1991)
Wattled	-	50%	West (1963)
	-	47%	Tarboton, Barnes & Johnson (1987)
Lesser Sandhill	-	60%	Boise (1977, in Tacha *et al.* 1989)
Greater Sandhill	97%	98%	Walkinshaw (1981a)
Florida	99%	-	Walkinshaw (1982, in Johnsgard 1983)
Sandhill	-	46%	Bennett & Bennett (1990)
	65%	-	Nesbitt (1992)

Appendix 1.7 Proportion of breeding pairs of cranes with fledged young in the post-breeding period.

Species	% pairs with young	Mean brood size	n= pairs	Source
Eurasian	48%	1,18	1847	Fernandez-Cruz (1981)
	55%	1,34	75	Nilsson (1982)
	41%	1,24	81	Bylin (1987)
	77%	1,42	1517	Prange & Mewes (1991)
Hooded	81%	1,29	42	Chishan & Xiaolun (1987)
Wattled				
Zam./Bots.	13%	1,00	254	Konrad (1981)
Kafue	20%#	1,00	64	Howard & Aspinwall (1984)
Kafue	12%	1,00	76	Howard (1989)
Bangweulu	34%	1,00	32	Howard & Aspinwall (1984)
Lesser Sandhill	60%*	1,00		Boise (1977, in Tacha *et al.* 1989)
	48%+	1,00		Tacha *et al.* (1989)
Greater Sandhill	53%	1,28	225	Walkinshaw (1955, 1965b)
Florida Sandhill	39%	1,44	365	Layne (1983)

- incomplete as count too early in the breeding season
* - on Alaskan breeding grounds
+ - post-migration in Texas and Nebraska

Appendix 1.8 Breeding productivity in cranes, expressed as the number of young reared per pair per annum. Y/pair/year - mean number of young reared per pair per annum; Y/br. pair/year - mean number of young reared per pair that attempted to breed (laid eggs) per annum.

Species	Y/pair year	Y/br. pair year	n= pairs	Source
Grey	-	1,00	12	Pomeroy (1980)
Crowned	-	0,58	12	Mafabi (1991)
Eurasian	0,57	-	1847	Fernandez-Cruz (1981)
	0,74	-	75	Nilsson (1982)
	0,51	-	81	Bylin (1987)
	0,87	1,01	146	Neumann (1987)
	-	1,09	1517	Prange & Mewes (1991)
Hooded	1,05	-	42	Chishan & Xiaolun (1987)
Whooping	*ca* 0,52	-	248	Novakowski (1966), Kuyt (1981) (both in Johnsgard 1983)
Demoiselle	-	0,88	17	Winter (1991)
Wattled				
Zam./Bots.	0,13	-	254	Konrad (1981)
Kafue	0,20#	-	64	Howard & Aspinwall (1984)
Kafue	0,12	-	76	Howard (1989)
Bangweulu	0,34	-	32	Howard & Aspinwall (1984)
Zimbabwe	0,60	-	5	West (1963)
Transvaal	0,41	-	94	Tarboton, Barnes & Johnson (1987)
Natal	-	0,23	-	Tarboton, Barnes & Johnson (1987)
Lesser	0,60*	-	-	Boise (1977, in Tacha *et al.* 1989)
Sandhill	0,48+	-	-	Tacha *et al.* (1989)
Greater	0,68	-	225	Walkinshaw (1955, 1965b)
Sandhill	0.74	-	67	Grewe (1977, in Walkinshaw 1981a)
	-	1,39	204	Walkinshaw (1981a)
Florida	0,56	-	365	Layne (1983)
Sandhill	0,70	-	287	Nesbitt (1992)

- Incomplete as count too early in breeding season
* - On Alaskan breeding grounds
+ - Post-migration in Texas and Nebraska

Appendix 1.9 Percentages of juveniles in various Sandhill Crane populations. Loc. type: B - on breeding grounds; M - during autumn migration, at staging and stopover sites; W - on wintering grounds.

Population	Locality	Loc. type	% juvs	n=	range	Source
Lesser	Alaska	M	7,2%	2108 inds	-	Herter (1982, in Johnsgard 1983)
	W. Texas	W	10,9%	-	9,2-13,7%	Tacha & Vohs (1984)
	W. North Dakota	M	10,6%	-	-	Tacha & Vohs (1984)
Canadian	Central Flyway	M	17%	-	-	Buller (1976, in Walkinshaw 1981a)
	-	-	18%	-	-	Aldrich (1979, in Walkinshaw 1981a)
	E. North Dakota	M	21,0%	-	-	Tacha & Vohs (1984)
	Oklahoma	M	14,0%	-	10,8-17,1%	Tacha & Vohs (1984)
	S. Texas	W	18,2%#	583 flks		Tacha *et al.* (1986)
Lesser &	Saskatchewan	M	4,8%	32837 inds	3,5-5,9%	Miller & Hatfield (1974)
Canadian	Central Flyway	M	11,6%	-	8,8-19,9%	Buller (1979, in Melvin & Temple 1983)
	North Dakota	M	-	-	10,9-15,9%	Melvin & Temple (1983)
Eastern	Michigan (1952-58)	B	19,4%	-	-	Walkinshaw *et al.* (1960, in Lovvorn & Kirkpatrick 1982b)
Greater	Michigan (1971-73)	B	14,0%	-	-	Walkinshaw & Hoffman (1974, in Lovvorn & Kirkpatrick 1982b)
	Minnesota (1977)	B	15,0%	333 inds	-	Grewe (1977, in Walkinshaw 1981a)
	Indiana (1977)	M	11,3%	9894 inds	-	Bennett (1978, in Lovvorn & Kirkpatrick 1982b)
	Indiana (1976)	M	13%	525 inds	-	Crete (1980, in Lovvorn & Kirkpatrick 1982b)
	Indiana (1977)	M	10,3%	4861 inds	-	Crete (1980, in Lovvorn & Kirkpatrick 1982b)
	Wisconsin & Indiana	M	11,5%	14442 inds	-	Crete & Grewe (1982, in Johnsgard 1983)
	Indiana (1979-80)	M	12,7%	21530 inds	11,9*-13,4+ %	Lovvorn & Kirkpatrick (1982b)
	Michigan (1984-86)	B	7,7%	-	4,8-9,9%	Urbanek *et al.* (1991)
Rocky						
Mountain	Idaho	M	-	-	13,0-14,0%	Drewien (1973, in Bennett & Bennett 1990)
Greater	New Mexico	W	11,5%	2658 inds	-	Drewien (1973, in Bennett & Bennett 1990)
Central						
Valley	Oregon	B	-	-	8-10%	Littlefield & Ryder (1968, in Bennett & Bennett 1990)
Greater	Oregon	B	6,6%	-	-	Scholorff *et al.* (1983, in Bennett & Bennett 1990)
Florida	Florida	B	15,6%	192 inds	-	Walkinshaw (1976, in Johnsgard 1983)
	Florida	B	10,1%	-	8,0-16,5%	Bishop (1988, in Nesbitt 1992)
	Georgia	B	8,8%	-	7,4-10,7%	Bennett & Bennett (1990)
	Florida	B	5%	100+	-	Dwyer & Tanner (1992)
	Florida	B	11,1%	-	7,8-13,6%	Nesbitt (1992)

- S.E.=0,6
* - S.D.=0,2
+ - S.D.=0,3

Appendix 1.10 Percentages of juveniles in various crane populations. Loc. type: B - on breeding grounds; MA - during autumn migration, at staging and stopover sites; MS - during spring migration, at staging and stopover sites; W - on wintering grounds.

Species	Locality	Loc. type	% juvs	n=	range	Source
Grey	Uganda	B	11,7%	534 inds	-	Brown & Pomeroy (1984)
Crowned	Transkei, South Africa	B	11,1%	72 inds	-	DGA (pers. obs)
Eurasian	-	-	12,0%	5808 inds	-	Libbert (1969, in Johnsgard 1983)
	Sweden (1967-68, 1973)	MA	5,6%	-	5-6,7%	Swanberg (1981)
	Scandanavia	MA	12,3%[1]	22740 inds		Prange & Mewes (1991)
	Central Europe	MA	-	-	14-16%	Prange & Mewes (1991)
	Spain (1979)	W	11,4%	17240 inds	-	Fernandez-Cruz (1981)
	Spain (1979-86)	W	13,5%	121826 inds	11,7-19,0%	Alonso *et al.* (1991)
	Finland	MA	8,1%	-	-	Jantunen *et al.* (1985, in Rinne 1991)
	Finland (1983-85)	MA	8,5%	3809 inds	-	Rinne (1991)
	Finland (1983-85)	MA	9,0%[2]	6137 inds		Karlin & Raivio (1987), Rinne (1991) (both in Prange & Mewes 1991)
	Estonia	MA	13,9%	8680 inds	12,4-15,4%	Keskpaik & Rinne (1986)
	Hungary	MA	-	22 flks	10-25%	Bankovics (1987)
	Hungary	MA	11,4%[3]	71497 inds		Sterbetz (1987, in Prange & Mewes 1991)
	India (1986)	W	15,4%	1043 inds	-	Khachar *et al.* (1991)
	China (1986)	W	15,5%	871 inds	-	Williams *et al.* (1991)
	China (1987)	W	12,7%	71 inds	-	Xiaojie (1991)
Hooded	Izumi, Japan (1968-72)	W	11,9%	2984 inds	2,0-20,0%	Nishida (1981)
	Yashiro, Japan (1983-85)	W	21,2%	188 inds	14,5-25,8%	Eguchi *et al.* (1991)
	China (1986)	MA	16,8%	309 inds	-	Williams *et al.* (1991)
	China (1985-87)	W	17,4%	236 inds	9,2-23,7%	Xiaojie (1991)
Whooping	Aransas, Texas (1938-52)	W	17,3%	-	-	Johnsgard (1983)
	Aransas, Texas (1953-66)	W	15,1%	-	-	Johnsgard (1983)
	Aransas, Texas (1967-80)	W	10,6%	-	-	Johnsgard (1983)
Redcrowned	Japan (1962-82)	B	12,7%	*ca* 4200 inds	6,8-20,9%	Masatomi (1979, 1981, in Johnsgard 1983), Archibald (1987)
	China (1980)	B	12,7%	173 inds	-	Yiching & Longrong (1987)
	China (1981, 1984)	B	16,7%[4]	362 inds	13,3-20,1%	Kemin & Zhongqin (1991)
	China (1986)	MA	21,8%	206 inds	-	Williams *et al.* (1991)
Sarus	Australia	B	16,7%	137 inds	-	Blackman (1971, in Johnsgard 1983)
Australian	Australia (1968-70)	B	17%	-	-	Blackman (1971, in Johnsgard 1983)
	Australia (1980)	B	10%[5]	*ca* 433 inds	-	White (1987)
Whitenaped	Japan (1968-72)	W	15,4%	1826 inds	11,2-21,6%	Nishida (1981)
	Korea	W	15%	*ca* 2000 inds	-	Archibald (1981a)
	China (1985)	W	24,7%	1241 inds	-	Bin & Zuoyi (1991)
	China (1986)	W	7,6%	157 inds	-	Xiaojie (1991)
	China (1986)	MA	16,0%	25 inds	-	Williams *et al.* (1991)
Demoiselle	India (1986)	W	8,7%	576 inds	-	Khachar *et al.* (1991)

Appendix 1.10 (cont.)

Species	Locality	Loc. type	% juvs	n=	range	Source
Wattled	Kafue	B	5,4%	147 inds	3,6-7,5%	Douthewaite (1974)
	Zambia/Botswana	B	4,2%	784 inds	0,0-9,5%	Konrad (1981)
	Transvaal	B	6,3%	711 inds	0,0-14,0%	Tarboton, Barnes & Johnson (1987)
Siberian	India (1969)	W	8,5%	65 inds	-	Walkinshaw (1973)
	India (1967-82)	W	14,3%	568 inds	9,1-26,1%	Sauey (1987)
	Yakutia, Siberia (1970's)	B	7,3%	41 inds	-	Flint & Kistchinski (1981, in Johnsgard 1983)
	Poyang, China (1981-82)	W	9,1%	321 inds	8,3-9,9%	Fuzhang & Wenning (1987)
	Poyang, China (1979-84)	W	14,5%	737 inds	-	Jinlu & Kemin (1991)
	Poyang, China (1981-86)	W	12,6%	3519 inds	10,9-14,8%	Bin & Zuoyi (1991)
	Dongting, China (1985-87)	W	23,1%	26 inds	-	Xiaojie (1991)
	Momoge, China (1985-86)	MA	22,5%	234 inds	20,9%-24,0%	Zhigang *et al.* (1991)
	Momoge, China (1985-86)	MS	17,5%	126 inds	-	Zhigang *et al.* (1991)
	Hebei, China (1986)	MA	21,9%	155 inds	-	Williams *et al.* (1991)

[1] - ±1,1%
[2] - ±4,4%
[3] - ±4,1%
[4] - 'sub-adults'
[5] - 'immatures and juveniles, 1-22 months old'

CHAPTER 2

THE DISTRIBUTION OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS*

SUMMARY

The Blue Crane Anthropoides paradiseus *is endemic to southern Africa. The vast majority of its range falls within South Africa. There are small breeding populations in Namibia and Swaziland, the species probably is only a non-breeding vagrant to Lesotho and Botswana, and no reliable records exist for Zimbabwe. In South Africa it is largely restricted to the grassland and fynbos biomes and parts of the Karoo biome. Within the grassland biome, its distribution is patchy in the central and western areas, and the species no longer occurs in Transkei. In the Karoo it is largely restricted to the Central Upper, Great and Steytlerville Karoos and its distribution remains unchanged from historical times. The Blue Crane is a relatively recent colonizer of agricultural areas in the fynbos biome and this colonization has been overlooked.*

2.1) *Introduction*

The Blue Crane *Anthropoides paradiseus* is endemic to southern Africa, with the vast majority of its population restricted to South Africa (Urban *et al.* 1986), where it is the national bird. The species is poorly studied (Archibald 1992), at least partly because it was thought until relatively recently to be ubiquitous and of little conservation concern. Walkinshaw (1973) and Johnsgard (1983) provide general accounts of the species in their respective monographs on the family. Two avian handbooks covering the region, Maclean (1993) and Urban *et al.* (1986), also contain brief summaries of the biology of this crane. Walkinshaw (1963) studied its breeding habits in the wild in Natal and Van Ee (1966) reports on the breeding behaviour of captive Blue Cranes. Several publications provide regional assessments of the population status of the species in various parts of its range. These include Tarboton, Kemp & Kemp (1987) for the Transvaal, Geldenhuys (1984) for the Orange Free State, Johnson & Barnes (1986) and Johnson (1992a) for Natal, Vernon *et al.* (1992) for the eastern Cape Province, Siegfried (1985) for the entire Cape Province, and Brown (1992a) for Namibia. Filmer & Holtshausen (1992) report on the distribution, abundance, habitat, breeding and conservation status of the Blue Crane drawn from a southern African crane census undertaken during 1985-1986. Several regional bird atlasses provide distribution maps of the species in various parts of South Africa (i.e. Cyrus & Robson 1980 - Natal, Earle & Grobler 1987 - Orange Free State, Tarboton, Kemp & Kemp 1987 - Transvaal, Hockey *et al.* 1989 - southwestern Cape Province). Some preliminary results of this review were presented in Allan (1992).

2.2) *Aims*

The aims of this study were to:

1) examine the current distribution, as assessed by bird atlas data, of the Blue Crane,
2) identify associations between the species' distribution and vegetation types,
3) review evidence of its historical distribution in the Karoo and fynbos biomes, and
4) show that the species is a relatively recent colonizer of the southwestern Cape, a fact previously overlooked.

2.3) *Methods*

A map of distribution records of Blue Cranes in southern Africa was obtained from the Southern African Bird Atlas Project (SABAP) (Harrison 1987, 1992). These records are plotted by quarter (*ca* 28 X 24 km, 15' X 15') or, in the case of Botswana, half (*ca* 56 X 48 km, 30' X 30') degree grid squares. The time periods covered by these data differ between regions in southern Africa (Underhill *et al.* 1991, Harrison 1992). The data from Namibia covers the period 1975-1993, from Botswana 1980-1992, from Swaziland 1986-1991, from the Orange Free State and the southwestern Cape 1983-1991, and from the eastern Cape 1985-1991. The data from the remainder of South Africa, Lesotho and Zimbabwe is restricted to the period 1987-1992. In all regions the majority of data are from the period 1987-1991, except for Namibia where slightly more data come from the period prior to 1987 compared to the period 1987-1993. The distribution map was then compared with several vegetation maps of the sub-region to search for associations between the distribution of the species and gross vegetation types. The vegetation maps examined were those of Acocks (1953), Giess (1971), Moll & Bossi (1983), Huntley (1984), Rutherford & Westfall (1986), Hilton-Taylor & Le Roux (1989), and Bekker & De Wit (1991).

Information from specific areas within the Blue Crane's range and on its historical distribution was extracted largely from published literature. Supplementary data from Lesotho and Transkei are provided, based on extensive bird surveys of these two areas by the author during 1991-1992.

2.4) *Results and discussion*

Figure 2.1 presents the SABAP distribution map for the Blue Crane in southern Africa. Figure 2.2 shows the boundaries of the various political units within southern Africa.

Namibia

The distribution of the species in this country is centred on the Etosha Pan (Figure 2.1). The vegetation in this area is distinct from the surrounding woodland regions and

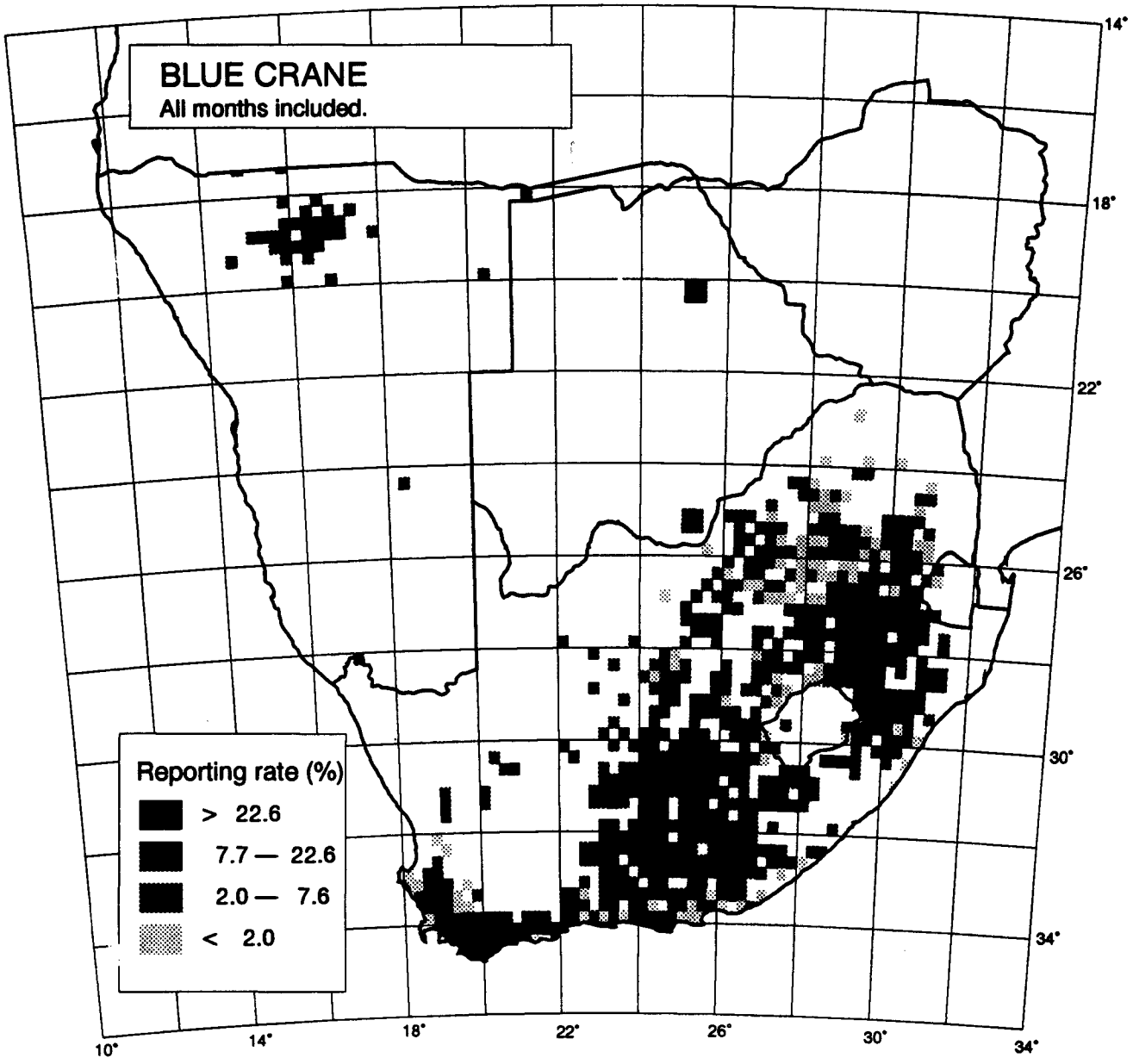

Figure 2.1 The distribution of the Blue Crane in southern Africa based on data from the Southern African Bird Atlas Project. Blue Cranes were recorded in all shaded squares. The intensity of shading represents the reporting rate, as shown in the key and discussed further in Chapter 3.

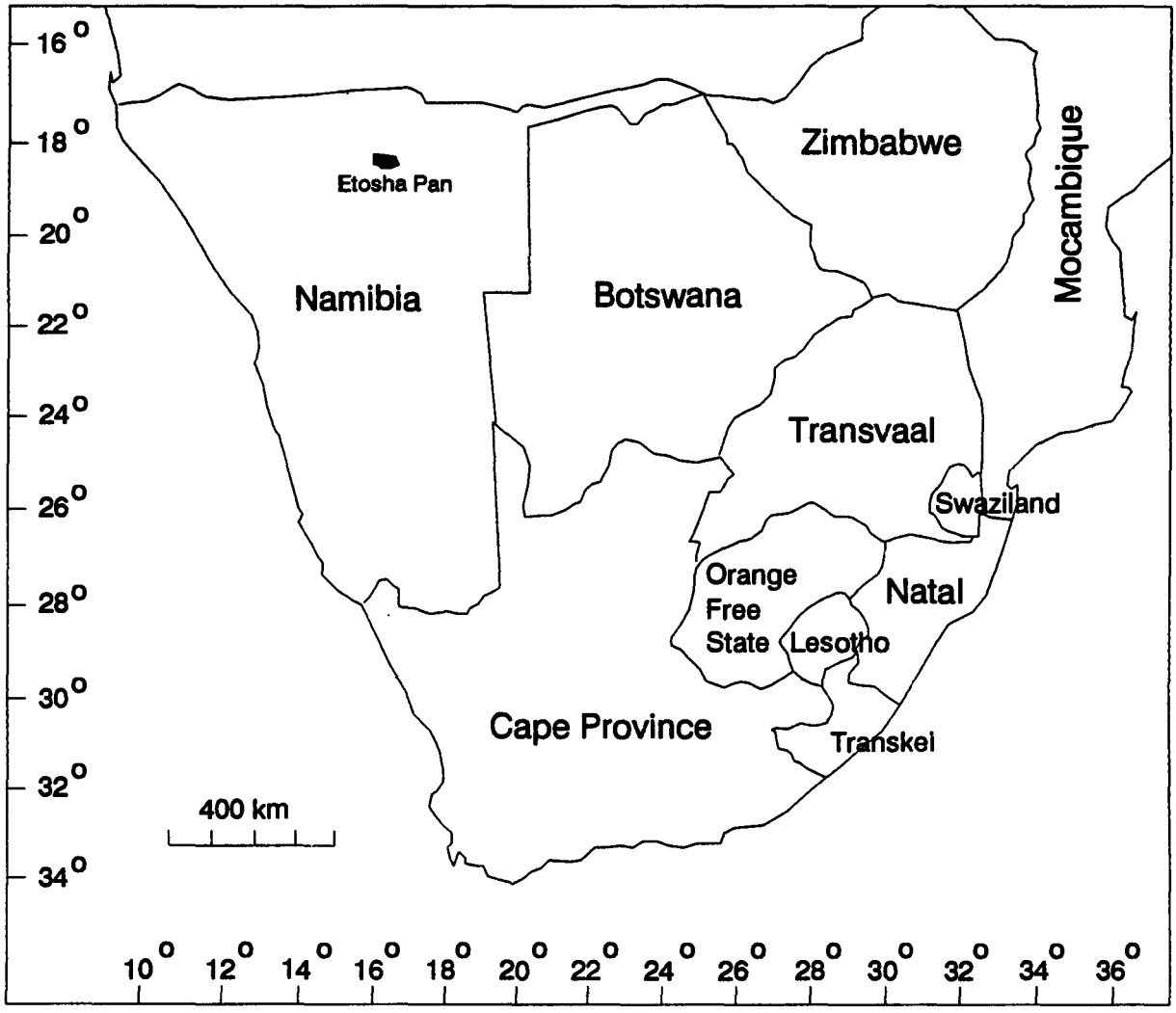

Figure 2.2 The boundaries of the various political regions in southern Africa.

is of limited extent. Giess (1971) characterizes it as "saline desert with dwarf shrub savanna fringe" and mentions that "extensive grass flats" occur in parts of this vegetation type. Brown (1992a) states the habitat of the species there to be "grassy plains" and estimates the extent of suitable habitat at 1400 km^2. The Etosha population of Blue Cranes is estimated at about 80 individuals (Brown 1992a). Occasional vagrants have been reported from elsewhere in the country both during (Figure 2.1), and prior, e.g. from Stampriet (24° 21'S 18° 24'E) (Winterbottom 1971), to the SABAP atlas period. The species frequently is kept in captivity (Allan 1985), however, and such out of range records may represent escapees. Until very recently no border control was in operation between this country and South Africa and therefore the uncontrolled transportation of captive Blue Cranes across this border into Namibia would have been easy.

Botswana

Blue Crane records come from two areas in Botswana, in the extreme southeast and the Makgadikgadi Pans in the northeast (Figure 2.1). Similar to the Etosha Pan area, the Makgadikgadi Pans comprise a vegetation type distinct from the surrounding woodlands and consist of grasslands (Bekker & De Wit 1991). The single record from this area is during the non-breeding period (May 1988, Bushell & Bushell 1989) and probably represents vagrancy. There are several records from within the woodland biome in the southeast . Most come from Good Hope Pan (25° 28'S 25° 27'E) (Anon. 1981b, Anon. 1982a, Anon. 1985, Bushell & Bushell 1989) with the single remaining record from Gaberone Dam (Anon. 1981a). These records probably represent non-breeding vagrants from the nearby Transvaal highveld breeding areas. All except one of these records occurred during the non-breeding season (April-June) or involved flocks of cranes. One record, from Good Hope Pan, was of a pair of birds during the breeding season (October). The total number of Blue Cranes present in Botswana at any one time has been estimated at 5-10 (Urban 1988).

Zimbabwe

The occurrence of the Blue Crane in Zimbabwe, an almost exclusively woodland region, is equivocal. Brooke & Borrett (1971), Irwin (1981) and Morris (1987) state that although several observations of the species in Zimbabwe have been claimed, none are unequivocal. The most recently published reports (Irwin 1986, de la Harpe 1989) similarly require confirmation. In the Transvaal, however, non-breeders regularly wander northwards into woodlands and the northernmost record is only 60 km south of the Zimbabwe border (Tarboton, Kemp & Kemp 1987).

Swaziland

The Blue Crane is a rare breeding summer migrant to the grasslands in the northwest of Swaziland (Parker in press). It occurs only at Malalotja Nature Reserve (26° 05'S, 31° 05'E) where the estimated population numbers 12 individuals. Its restriction to a nature reserve in this country, despite large surrounding areas of apparently suitable grassland habitat (Figure 2.3), suggests that the high human density (average of 39 persons per km^2, Anon. 1991) is responsible for its absence from the rest of Swaziland, similar to the situation described below for Lesotho and Transkei.

Lesotho

The Blue Crane is a rare non-breeding visitor to Lesotho where probably no more than 10 birds are present at any one time (Osborne & Tigar in press). Less than 20 records exist for the species in this country (Bonde 1993, Osborne & Tigar in press). Its scarity is surprizing as Lesotho would appear to offer superficially suitable grassland habitat (Figure 2.3) but its rarity there dates back to at least 1963 (Jacot-Guillarmod 1963). The scarcity of Blue Cranes in Lesotho was confirmed by personal observations. I visited the country twice (22 February-9 March and 24 June-1 July 1991) during the course of this study to investigate its birdlife. Twenty-two of the approximately 60 quarter degree squares (37%) covering the country, all in the northern half, were visited and searched for birds. About 2400 km were driven during 24 days in the country. No Blue Cranes were encountered.

The extreme steepness of the topography, the high altitude (>2500 m), and the dense human population (average of 40 persons per km^2) of most of the country (Osborne & Tigar in press), or a combination of these factors, probably are responsible for the scarcity of Blue Cranes in Lesotho. Although the high altitude (>3000 m) and topography may be implicated in its absence from the central and eastern parts of the country, the presence of the species in parts of South Africa where human densities are much lower and which are adjacent to the lower-lying regions of Lesotho in the south and west suggests that the dense human population is the limiting factor in these areas. The intensive livestock grazing practices (Osborne & Tigar in press), incidental disturbance, active persecution, and loss of habitat which are associated with high human densities may be responsible for excluding the species from these parts of Lesotho. Most of the human population is concentrated in these low-lying regions (Osborne & Tigar in press).

South Africa

A comparison of the distribution map of the Blue Crane (Figure 2.1) and a map showing the biomes of South Africa (Figure 2.3) shows that in this country the species largely is restricted to three biomes: the grassland, Karoo and fynbos.

Tarboton, Kemp & Kemp (1987) comment that there is a small, isolated breeding population on the open grassland plateaus of the Waterberg in the woodland biome of the northern Transvaal and that vagrants occasionally are encountered elsewhere in the woodlands of the central and northern Transvaal (see also Figures 2.1 and 2.3), e.g. 35 at Rust de Winter Dam (25° 14'S, 28° 29'E) on 12 June 1983, a pair seen near Dwarsberg (25° 06'S, 26° 37'E) on 13 April 1990, and birds heard calling near Pietersburg (24° 01'S, 29° 28'E) on 24 July 1990 (pers. obs).

Grassland

Within the grassland biome the distribution of the species is more patchy in the central and western sweet and mixed grasslands compared to the eastern sour grasslands (Figure 2.1, Acocks 1953). In the Transvaal, for example, Tarboton, Kemp & Kemp (1987) state the species to be most common in the eastern highveld and estimate the total population there to number in excess of 1000 individuals. Smallstock farming using natural grazing is the major agricultural practice in sour grassland areas which are largely unsuitable for crop farming (Tarboton, Kemp & Kemp 1987). This is in contrast to the other two grassland areas where crop farming is extensive. The high human densities (Geldenhuys 1984), alteration of habitat, and use of poisons associated with large-scale crop farming probably are responsible for the patchy distribution of the Blue Crane in the west and central parts of the grassland biome. Its remaining stronghold in the sour grasslands is threatened by burgeoning commercial afforestation in this region (Johnson 1992a). The grassland biome is both the most modified vegetation type in South Africa (65-70% converted by cultivation, Macdonald 1989) and one of the least well protected (2% of its total area protected in nature reserves, Siegfried 1989).

A feature highlighted by Figure 2.1 is the absence of the species from Transkei. Most of this region comprises sour grasslands and would appear to offer suitable habitat. The species is found in all the adjacent parts of South Africa to the north, south and west in similar habitat. It is likely that the high human densities in Transkei (average of 78 persons per km^2, Macdonald 1989, O'Connor 1991), compared to the adjacent parts of South Africa, are responsible for the absence of Blue Cranes there (Vernon *et al.* 1992), similar to the situation in the lower-lying parts of Lesotho. The scarcity of the species in Transkei also is commented on by Skead (1967) and Quickelberge (1989) and it has been a rare species there since at least the 1920's (Vernon *et al.* 1992). Personal

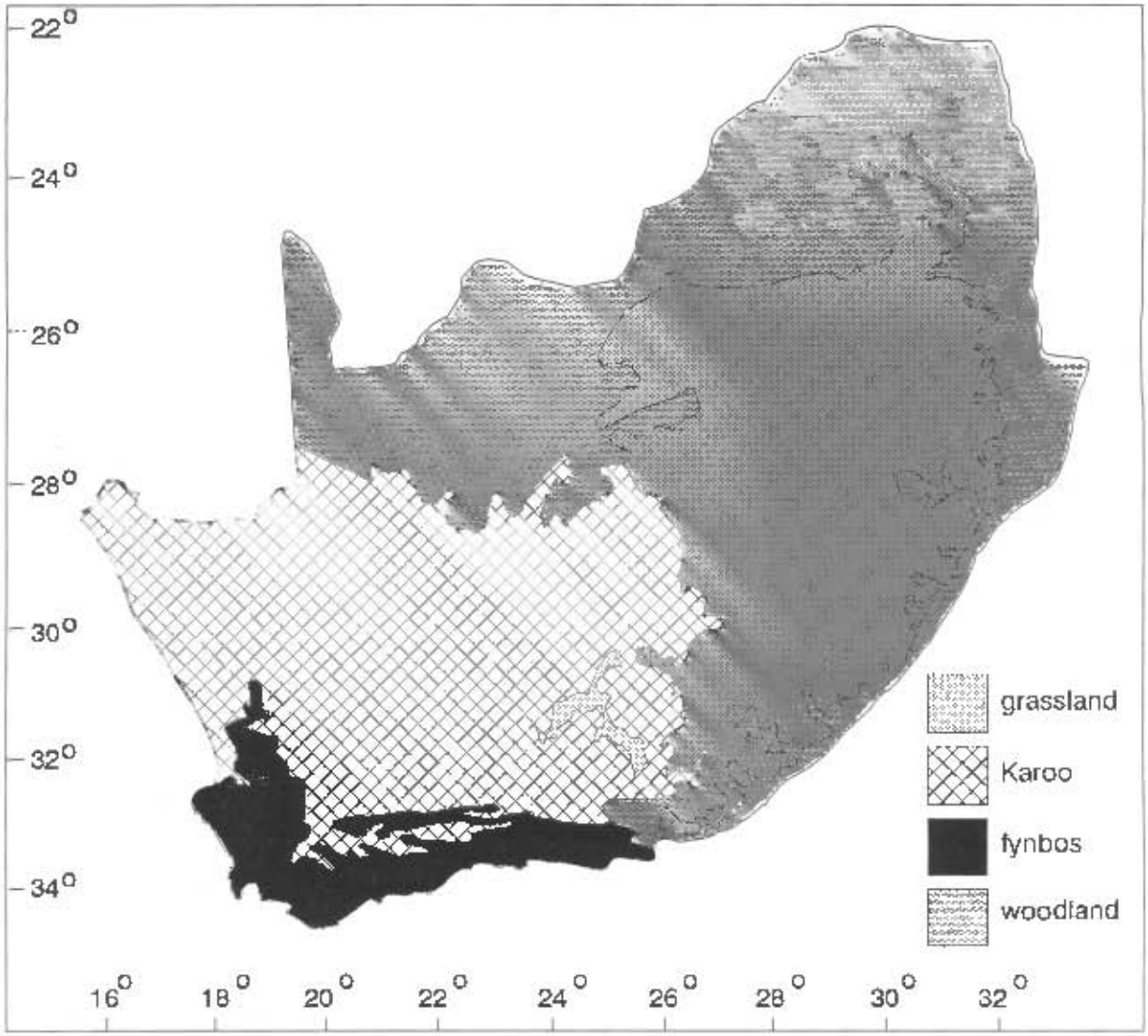

Figure 2.3 The four major biomes of South Africa (based on Huntley 1984).

observations confirmed this rarity. I visited Transkei four times between September 1990 and February 1992 (Sept.-Oct. 1990, March 1991, Sept.-Oct. 1991, Feb. 1992) to survey birdlife there. Fifty-eight of the approximately 85 quarter degree squares (68%) covering this region were visited, 55 days were spent in the field and about 11 800 km were travelled. No Blue Cranes were seen but Grey Crowned Cranes *Balearica regulorum* were encountered on 51 occasions. The persistence of the Grey Crowned Crane in Transkei, despite the dense human population, probably is due to human sentiment in the area (Quickelberge 1989) and the secretive, wetland nesting habits of this species (Tarboton 1992a) compared to the Blue Crane which nests in exposed locations on dry ground (Walkinshaw 1963).

The present distributional limits of the Blue Crane in the grassland biome probably are similar to the ancestral range except for the retraction of the species from Transkei, most of Swaziland and the lower-lying parts of Lesotho. Although it appears to have suffered local decreases elsewhere in this biome, especially in the sweet and mixed grassland regions, it is still reported from most of the remainder of this biome.

Karoo

The distribution of the Blue Crane in the Karoo is limited within this biome (Figures 2.1 and 2.3). A comparison of Figure 2.1 and a map of biogeographic areas in the Karoo (Figure 2.4) shows that it is largely restricted to the extreme east of the Nama Karoo biome, essentially the Central Upper Karoo, Great Karoo and Steytlerville Karoo. Indeed, even within these three biogeographic areas it is largely restricted to the eastern parts of these regions. The species is rare or absent in the Bushmanland, Karas and Gordonia regions of the Nama Karoo and throughout the succulent Karoo.

The restriction of the species to only part of the Karoo raises the question of whether it has retracted in range in this biome. Its current distribution in the Karoo, however, probably is little different from its ancestral range there. The parts of the Karoo where it is found differ from the remainder of the Karoo in rainfall and vegetation patterns. It is the only part of the Karoo where rainfall both exceeds 300 mm per annum and falls within the summer rainfall region (Schulze 1965). It is also the only part of the Karoo where perennial grasses dominate over the dwarf shrublands typical of the remainder of the biome (Hoffman & Cowling 1990). It has been suggested that, in this part of the Karoo, perennial grasslands have been invaded by dwarf shrublands in recent times due to anthropogenic influences (livestock grazing regimes) (Acocks 1953). This has been questioned (Hoffman & Cowling 1990), however, and it seems likely that climatic factors, rather than anthropogenic ones, are decisive in dictating the vegetation at this interface between the dwarf shrublands of the Karoo proper and the grassland biome. This strongly suggests that these climatic and

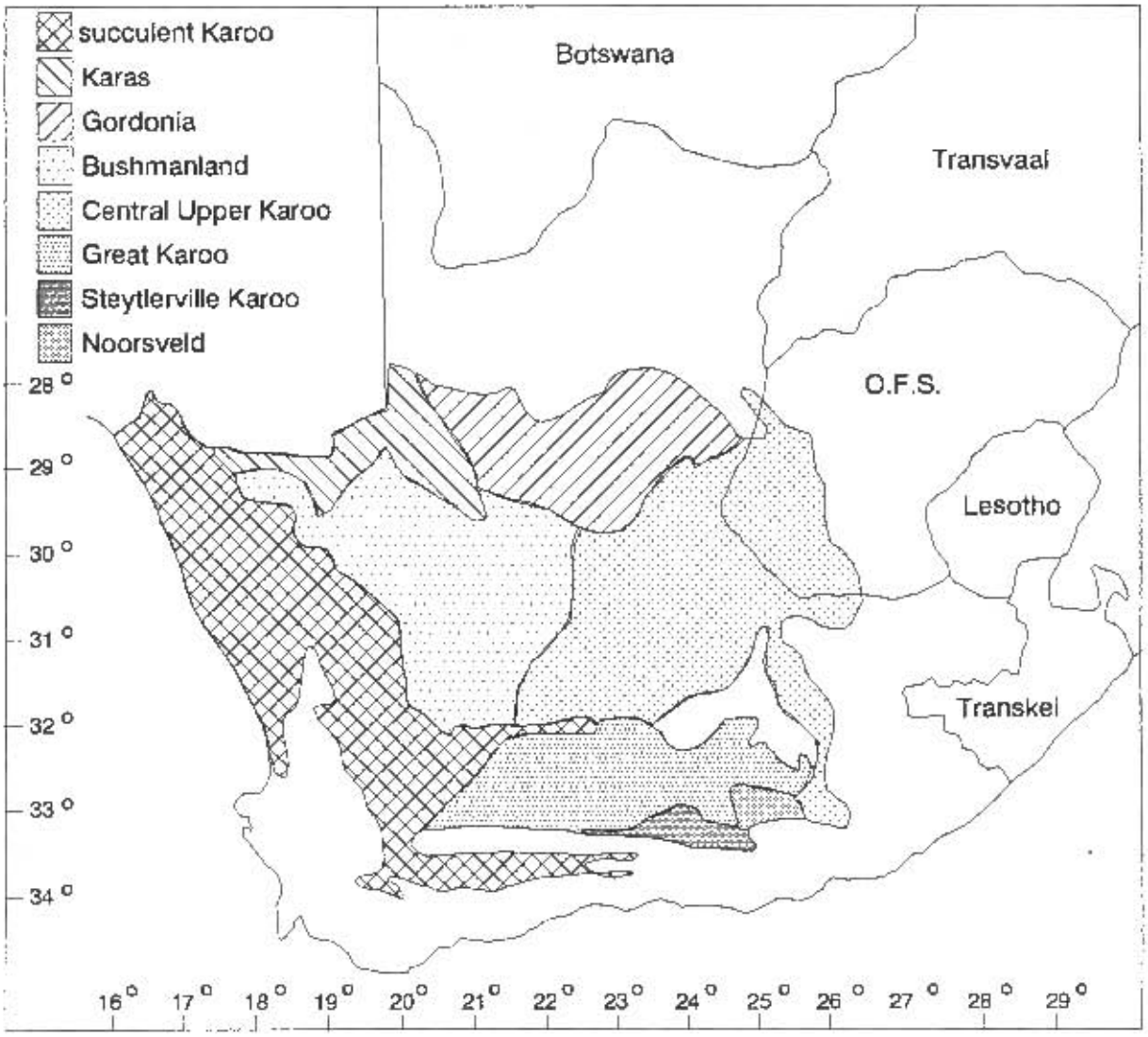

Figure 2.4 The Karoo biome in South Africa showing the boundaries of the succulent Karoo and the various Nama Karoo biogeographic areas (based on Hilton-Taylor & Le Roux 1989).

botanical factors, rather than any anthropogenic influences, dictate the limits of the range of the Blue Crane in this biome. Unlike the grassland biome, the Karoo is too arid for widespread crop farming and commercial afforestation, with less than 1% being cultivated (Macdonald 1989), and human densities in this region are low (average of less than five persons per km^2, Walton 1984). Therefore the potential threats of habitat loss, disturbance and poisoning are low in this biome and the poor protection status of the Karoo (less than 1% in nature reserves, Siegfried 1989) is of little significance.

In addition, a review of historical records does not suggest that there has been any change in the limits to the range of Blue Cranes in the Karoo within the recent past. R.J. Gordon recorded Blue Cranes near Bethulie in 1777 (Rookmaaker 1989). Layard (1867) recorded the species 'continually' at Nelspoort and reported that it bred 'in some abundance' at Colesburg. Sclater (1906) reports two additional Karoo localities, Deelfontein and Hopetown. James (1921) found the species to be a common breeding bird in the Cradock District, with flocks of 20-300 reported. Quinton & Winterbottom (1968) mention two localities near Beaufort West and Winterbottom (1970) recorded the species at four localities near Richmond. Winterbottom (1968) reports the species to be common in the western Cape Karoo only in the Philipstown-De Aar-Richmond area. Kieser & Kieser (1978) report the Blue Crane to be resident throughout the De Aar District and often found in flocks of more than 100 individuals. Collett (1982) comments that this crane is a widespread breeding species in the Cradock District, with flocks of up to 150 individuals recorded, but suggests that it has decreased there over the previous 50 years. All of these historical localities, which are shown in Figure 2.5, are in the Central Upper Karoo and Great Karoo. Siegfried (1985) reports on an extensive series of road counts made throughout the Cape Province during 1965-66. Blue Cranes were not recorded in the succulent Karoo and were restricted largely to the central and eastern Karoo. Nor were Blue Cranes recorded in the succulent Karoo by Winterbottom & Courtney-Latimer (1961) or Winterbottom (1966a, 1966b, 1972). Geldenhuys (1984) recorded the Blue Crane as a common and widespread breeding species throughout the Orange Free State during 1972-82, including the southwestern section which comprises Central Upper Karoo.

Fynbos

Figures 2.1 and 2.3 show that the Blue Crane is widespread in the fynbos biome. As discussed more fully in Chapter 6, the species largely is restricted to intensively cultivated habitats, mainly cereal crops and smallstock farming areas, in this biome and largely is absent from areas of natural vegetation. Winterbottom (1978) comments that the birds inhabiting the agricultural areas of the fynbos biome are characteristic of

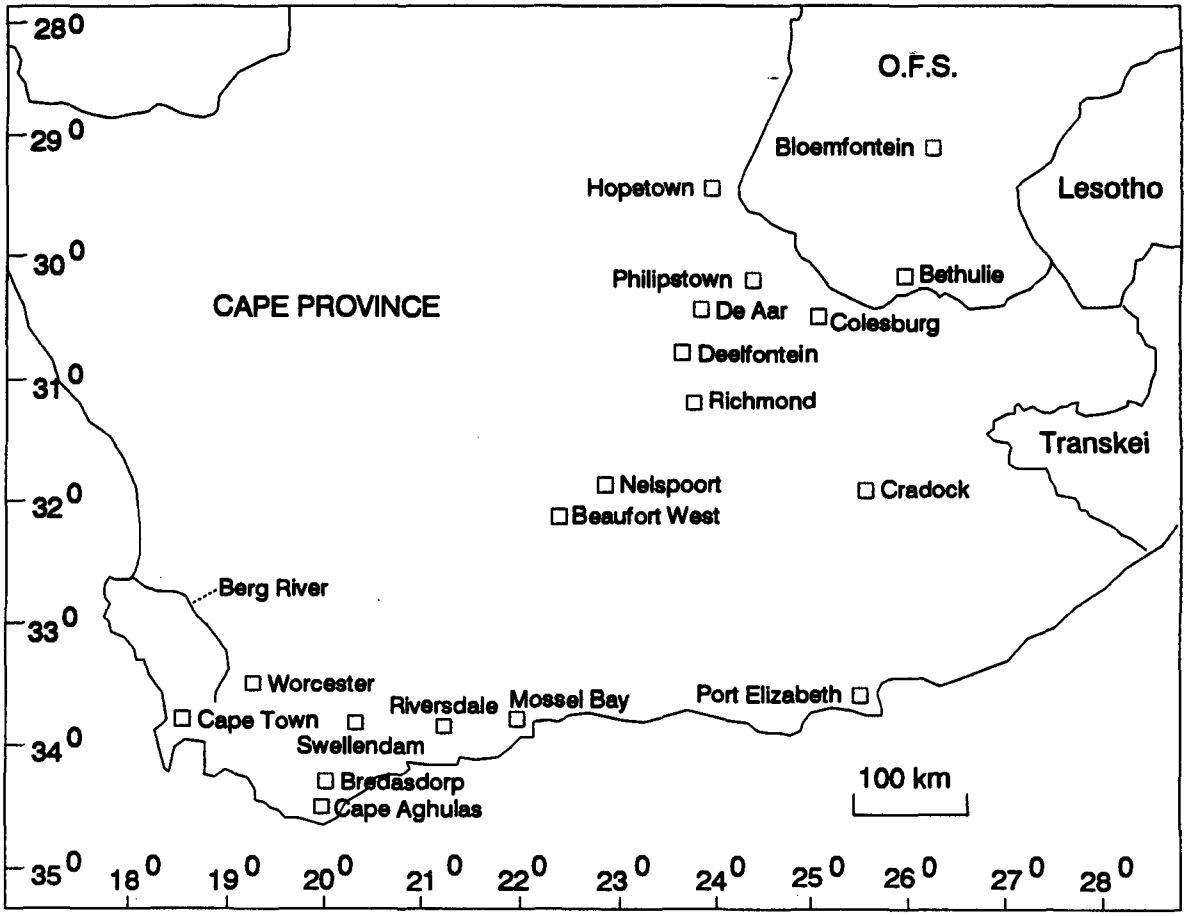

Figure 2.5 Map showing the localities of the various historical records of Blue Cranes in the Karoo and fynbos biomes mentioned in the text.

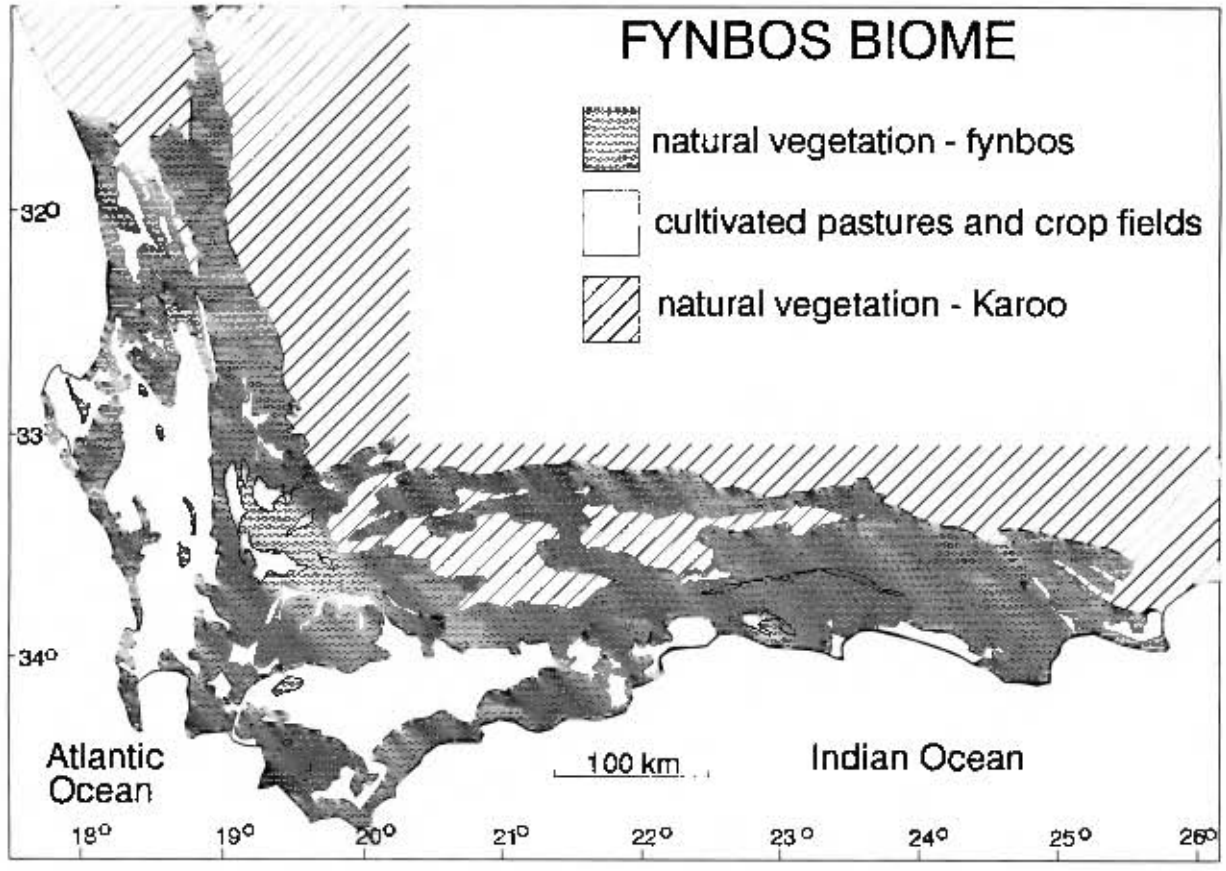

Figure 2.6 The fynbos biome in South Africa showing areas of natural vegetation and cultivated land (based on Moll & Bossi 1983).

grasslands and not the indigenous vegetation of this biome. Figure 2.6 shows the boundaries of the fynbos biome and the extent of the areas transformed by cultivation.

The restriction of the Blue Crane to agricultural areas in the fynbos biome (see Chapter 6) raises the question of whether the species was present in this region before the advent of widespread cereal crop farming. A review of historical records, the locations of which are shown in Figure 2.5, suggests that it is recent colonizer, subsequent to the establishment of extensive cereal crop farming, which occurred during the period 1820-1890 (de Kock 1924). R.J. Gordon (Rookmaaker 1989) reported that Blue Cranes were not found in the vicinity of Cape Town during 1770-80, nor did they occur within '100 hours' journey to the east of this city, i.e. within 320-550 km (Forbes 1965) or beyond Mossel Bay. The earliest record of the species in the region was by Victorin, who recorded it at Mossel Bay in 1884 (Grill 1958). It is only subsequent to this that records appear from throughout its present range in the southwestern Cape. Sclater (1906) mentions a specimen from the Berg River area in the western Cape, collected at the turn of the century. An observer familiar with the southern Cape since about 1930 reports that Blue Cranes (and extensive cereal farming) were present in the area in 1930 and probably since at least the turn of the century (Prof. C.J. Uys pers. comm.). Gill (1936) reports the species to be "not unknown near the south coast". Robinson *et al.* (1957) reported the species in the area between Bredasdorp and Cape Agulhas during 1939-1957. The Cape Bird Club checklist (Anon. 1955) mentions several localities in the western and southern Cape, including a breeding record from near the location of the original Bontebok National Park close to Bredasdorp. The earliest breeding record from the southwestern Cape in the nest record card collection of the Southern African Ornithological Society is from near Bredasdorp in 1958 and there are an additional nine records from the 1960's. Checklists of the birds of the Swellendam (Winterbottom 1962a), Worcester (Winterbotton 1962b), and Mossel Bay (von Etzdorf & Winterbottom 1967) districts include Blue Cranes, but a similar list for the Riversdale District (Winterbottom 1966c) does not. Siegfried (1985) recorded the species in both the western and southern parts of the fynbos biome during road counts made during 1965-66. Winterbottom (1968) reported the species to be present throughout the southwestern Cape but common only in the area between Bredasdorp and Mossel Bay. None of these sources, however, provide any indication of the species being as abundant in the southern areas of the fynbos biome as was found during this study (see Chapter 3). The extirpation of large, and the intensive control of small, mammalian predators in the cereal and sheep farming areas of the southwestern Cape also may have contributed to the colonization of the region by the Blue Crane as a breeding species.

That the Blue Crane is a relatively recent colonizer of the fynbos biome has been overlooked. For example, Hockey *et al.* (1989) do not include it in their list of species thought to have increased in the southwestern Cape in recent times. Brooke & Vernon (1988) in their review of the historical distribution of the Wattled Crane assumed that both species occurred in the southwestern Cape at the time of early European colonization. It is likely that only Wattled Cranes occurred west of at least 22° in the fynbos biome prior to the establishment of extensive cereal crop farming in the region and therefore sometime during the period 1820-1890.

CHAPTER 3

THE ABUNDANCE OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS* IN SOUTH AFRICA AS ASSESSED BY BIRD ATLAS DATA AND ROAD COUNTS

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SUMMARY

The abundance of the Blue Crane Anthropoides paradiseus *in various regions of South Africa was estimated using bird atlas reporting rates, road counts, line transect counts and aerial censuses. Measures of relative abundance based on atlas reporting rates and road counts appeared positively correlated and the nature of this association was logarithmic. Blue Cranes were most abundant, i.e. occurred at highest density, in the southern Cape (fynbos biome), followed by the eastern Karoo (Central Upper, Great and Steytlerville Karoo regions) and eastern parts of the grassland biome, and were least common in the Swartland (southwestern Cape, fynbos biome) and the western parts of the grassland biome. The total population estimate for South Africa, where more than 99% of the world population is found, was 20800 individuals (fynbos - 5600, Karoo - 5800, grassland - 9400).*

3.1) *Introduction*

In addition to showing the distributional limits of species, bird atlas data also can be used to assess relative abundance based on measures of reporting rates, i.e. the percentage of checklists on which a species is recorded relative to the total number of checklists for any particular area. Useful reviews and discussions of the use of reporting rates are provided by Harrison (1989) and Underhill *et al.* (1991, 1992). The use of reporting rates was introduced by Linsdale (1928) and was first used in southern Africa by Vernon (1967). The first extensive incorporation of reporting rates in a bird atlassing project was by Temple & Temple (1986) and the first southern Africa atlas to exploit this method of assessing relative abundance was the atlas of the birds of the southwestern Cape region (Hockey *et al.* 1989). Potential problems associated with the mis-interpretation of reporting rate data are discussed in Underhill *et al.* (1992).

Road counts have been used widely in assessing the abundance of birds since the technique was introduced in the 1920's (Nice & Nice 1921). Its best known application is in studies of birds of prey. Fuller & Mosher (1987) and Millsap & LeFranc (1988) provide useful discussions and examples of raptor road count studies in North America. The technique has been ubiquitous in southern African raptor research and examples

include Rudebeck (1963) who published the first local counts from the 1950's, Rowan (1964), Siegfried (1966, 1968), Cade (1969), Dean (1975), Vernon (1979), Schmitt *et al.* (1980, 1982), Tarboton & Allan (1984), Brown (1986a, 1986b), Brown *et al.* (1987), Knight (1987), Schmitt *et al.* (1987), Watson (1990), and Brown (1992b). Brown & Biggs (1984) provide a full description of the rationale and methods of an ongoing raptor road count project in Namibia and Botswana.

Road counts also have proved useful with other conspicuous birds, including relatively small passerines. Indeed the first published road counts (Nice & Nice 1921) were of small birds, mainly passerines. Other examples of road counts of non-raptors include Cleland (1919, 1922a, 1922b) (various Australian birds), Howell (1951) (various North American passerines and near-passerines), Brereton (1977) (Australian parrots), Gill (1977) (various New Zealand birds), and Hermes (1986) (Indian Mynas *Acridotheres tristis* in Australia). Southern African examples include road counts of corvids (Winterbottom 1975), counts of various species, e.g. herons, bustards, plovers, coursers, sandgrouse, pigeons and doves, in the Kalahari Gemsbok National Park (Macdonald 1982), and counts of Redbacked Shrikes *Lanius collurio* (Bruderer & Bruderer in press). Road counts have been used to assess the abundance of Eurasian *Grus grus*, Demoiselle *Anthropoides virgo* and Sandhill *G. canadensis* Cranes in India and North America (Lovvorn & Kirkpatrick 1982, Tacha *et al.* 1986, Pogson & Lindstedt 1991, Khachar *et al.* 1992). Particularly relevant to this study, Siegfried (1985) reports on an extensive series of road counts of Grey Crowned *Balearica regulorum* and Blue *A. paradiseus* Cranes made in the Cape Province during 1965-1966 and Vernon *et al.* (1992) present similar counts of the same two species for the eastern Cape Province made during 1977-1987.

Many road count studies are relatively unsophisticated and are based on the number of birds recorded per unit of time or distance (e.g. Tarboton & Allan 1984). Such data allow comparisions of relative abundance between different localities, time periods or species. More sophisticated approaches incorporate some measurement of the distance between the bird and the observer such that absolute abundances or densities can be estimated. In the latter studies two approaches are adopted, strip and line transects. In strip transects, only birds seen within a fixed distance from the transect line are counted (e.g. Bruderer & Bruderer in press). More detailed strip transect counts can employ more than one 'belt' in calculating densities (Bibby *et al.* 1992). In line transects the estimate of density is based on measurements of the individual distances between the birds and the transect line irrespective of how far away from the transect line they are (e.g. Watson 1990).

These more sophisticated techniques are identical in principle to transect counts made on foot and usually are used when the relevant species occur at densities too low for other methods. A plethora of literature exists on censusing birds and other biological populations using transect counts and other methods of estimating abundance. Several confounding variables, e.g. observer speed (Allan 1990), can affect the accuracy and precision of counts. Indeed, Temple (1981) suggests that all alleged measures of absolute abundance are really nothing more than measures of relative abundance. The major contributions to, and reviews of, bird census methodology can be found in Ralph & Scott (1981), Taylor *et al.* (1985), Verner (1985), and Bibby *et al.* (1992). Burnham *et al.* (1980) present the definitive approach to line transect estimates of biological populations.

Some preliminary results of this study were presented in Allan (1992).

3.2) *Aims*

The aims of this study were to:

1) assess the relative abundance of Blue Cranes in various regions within their range in South Africa using bird atlas data (reporting rates),

2) assess the relative abundance of Blue Cranes in various regions of the Karoo and fynbos biomes using road counts,

3) compare the information on relative abundance from atlas data and road counts,

4) estimate the absolute abundance of the species in the southern Cape using line transect counts made from a motor vehicle and compare this estimate with that obtained from two unpublished aerial censuses, and

5) provide estimates of the total population size in the Karoo and Swartland by interpreting the road counts made in these regions as simple strip transects, with the strip width based on measurements of perpendicular sighting distances.

3.3) *Study areas and methods*

Atlas data

Atlas data on the distribution and reporting rates of Blue Cranes in South Africa were obtained from the Southern African Bird Atlas Project (SABAP, Chapter 2). Reporting rates were calculated for each of nine regions within the South African range of the species. The reporting rate for each region represented the mean of the reporting rates from each square considered individually in that region, and was not based on the percentage of checklists recording the species considering all checklists for the region combined. A generalized linear model with a binomial distribution and logistic link

function (McCullagh & Nelder 1989) was used to test for significant differences in reporting rates between regions.

Road counts

Road counts were made in the Karoo and fynbos biomes of South Africa between August 1988 and July 1993. The boundaries of the Karoo and fynbos biomes, and the various biogeographic sub-divisions within the Karoo, used in this study are those provided by Hilton-Taylor & Le Roux (1989) and Moll & Bossi (1983) respectively.

Four road count routes were established. Two were in the Karoo, one through the western and the other through the eastern Karoo. The remaining two were in the fynbos biome, one on the southern coastal plain between Botrivier and Mossel Bay ('southern Cape') and the other on the western coastal plain between Durbanville and Piketberg (the 'Swartland'). The routes followed secondary (gravel) roads wherever possible. The Karoo routes were each travelled four times, twice in the winter (June - July) and twice in the summer (November - March). The southern Cape route was done 15 times, covering all months except January and October. The latter route was altered after the first two transects by excluding an 83 km stretch through tall, dense indigenous vegetation and substituting an alternate route through agricultural areas more typical of the balance of the transect. The habitat traversed in the original stretch was unsuitable for cranes and none were seen there during the first two transects. The Swartland route was done twice, once in the summer (December) and once in the winter (July).

Figure 3.1 shows the various biogeographic areas of the Karoo (after Hilton-Taylor & Le Roux 1989) and the routes followed during the eastern and western Karoo road counts. Figure 3.2 shows the boundaries of the fynbos biome, the areas comprising natural vegetation and cultivated regions within this vegetation zone (after Moll & Bossi 1983), and the road count routes through the southern Cape and the Swartland. Appendix 3.1 lists the dates and the number of kilometres travelled during each count. These data are presented separately for each biogeographic region of the Karoo. The slight differences in distances between counts through the same areas at different times are due to minor logistical factors inherent to the large distances traversed. The distances covered in the first two southern Cape counts differ substantially from the remainder through this study area due to the re-routing of the stretch through the unsuitable habitat.

The counting technique was standardized for all of the counts. Two observers, including the driver, were used. The driver attempted to maintain a constant speed of 50 km/hour. Counts were stopped while travelling through built-up areas. On seeing a

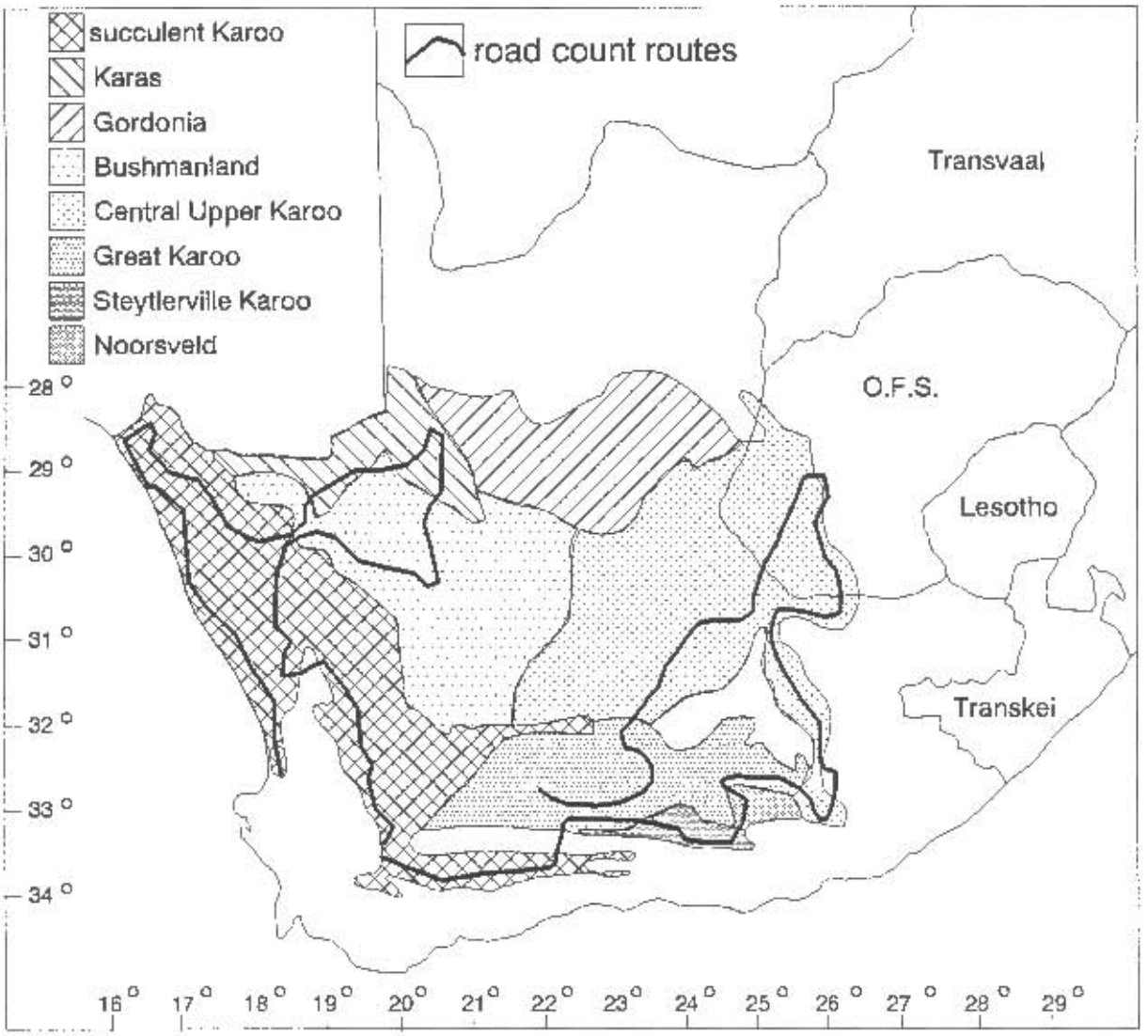

Figure 3.1 The Karoo biome in South Africa showing the road transect routes (thick lines) and the boundaries of the succulent Karoo and the various Nama Karoo biogeographic areas (based on Hilton-Taylor & Le Roux 1989).

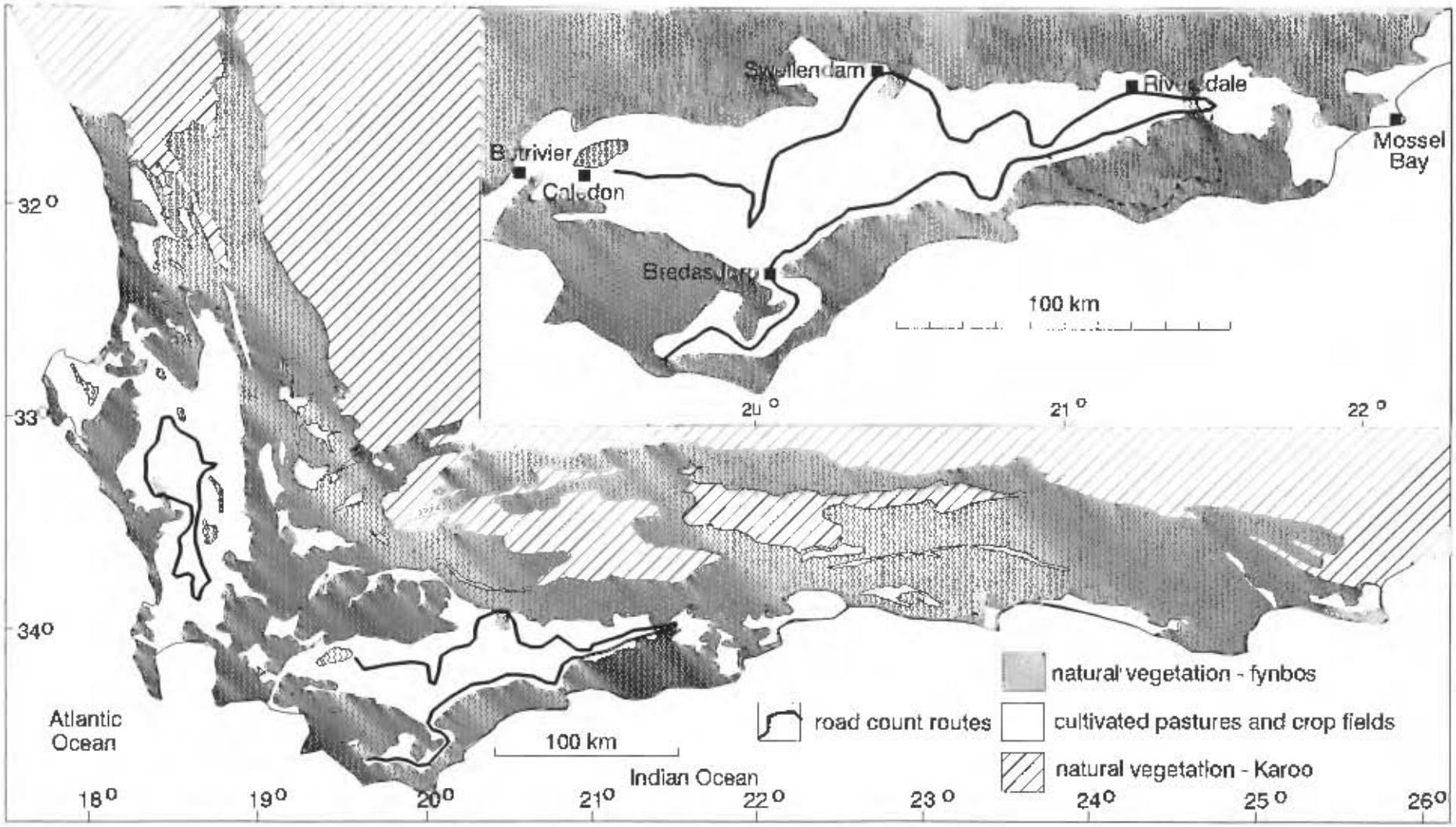

Figure 3.2 The fynbos biome in South Africa showing the routes of the southern Cape (east) and Swartland (west) road transects, and areas of natural vegetation and cultivated land (based on Moll & Bossi 1983). The inset shows details of the southern Cape study area and transect route. In the inset the 83 km stretch through natural vegetation that was excluded after the first two transects is shown by the dashed line.

group of cranes, the vehicle was stopped briefly, the group was examined through a telescope, and details of the time of day, locality, group size, age classes, activity, habitat, and height of the surrounding vegetation were recorded. During the stop, all cranes visible in the area were considered as part of the same group even if they were relatively widely dispersed. Blue Crane chicks, i.e. less than full size and incapable of proper flight, were not included in the counts.

During the last count through each of the Karoo regions and on all but the first two counts in the southern Cape, the perpendicular distance from the centre of the group of cranes to the transect line (road) was calculated. This was done by measuring the sighting distance using a rangefinder and the sighting angle using a hinged ruler and a protractor. The perpendicular distance was calculated according to the equation $y=r\sin\theta$, where y represents the perpendicular distance, r represents the sighting distance and θ represents the sighting angle (Burnham *et al.* 1980). During part of the final count in the eastern Karoo and during the fourth count in the southern Cape damage to a rangefinder necessitated the measuring of perpendicular distances by pacing out distances on foot. These data were used to estimate the density of cranes in the southern Cape study area using the computer program 'TRANSECT' (Laake *et al.* 1979, Burnham *et al.* 1980).

Aerial transect counts

Unpublished data on crane densities and relative abundances from two aerial counts in the southern Cape study area made by members of the Cape Bird Club on 26 January and 26 July 1986 were obtained from Dr P.A.R. Hockey of the Percy FitzPatrick Institute of African Ornithology, University of Cape Town. These were compared with similar data from the road counts made during this study. The counts were made from a light aeroplane and were restricted to the agricultural area between Caledon and Mossel Bay, the same area covered by the road transects. An identical route of 581 km was surveyed on both flights. All cranes seen within an estimated 500 m of the aircraft were included in each count, giving an effective transect width of about 1000 m.

3.4) *Results*

Relative abundance in South Africa based on atlas data

Figure 2.1 (Chapter 2) presents the SABAP distribution map for the Blue Crane and shows the reporting rate for each grid square in which the species was recorded. Four classes of reporting rate are shown. The first is squares where the species has been recorded on less than two percent of checklists. The remaining three are squares where

the species has been recorded on more than two percent of checklists and these have been classed into the three categories by dividing the data into three equal quantiles. Figure 3.3 shows the nine regions in South Africa within which reporting rates for each grid square were amalgamated and compared with the other regions. Table 3.1 lists the nine regions and provides the relevant reporting rate statistics for each.

The application of generalized linear modelling to test the statistical significance of the differences in mean reporting rates between the various regions suggested that: 1) the southern Cape reporting rate was significantly higher than in any other region; 2) the Swartland and western grassland had reporting rates which were not significantly different but which were both significantly lower than any of the other regions; and 3) the remaining three grassland regions (eastern grassland, Natal grassland and eastern Cape grassland) and the three Karoo regions had reporting rates not significantly different from one another. These deductions were based on comparisons of changes of the deviance in a nested series of models; any further lumping of regions resulted in a large increase in the residual deviance.

Relative abundance in the Karoo and fynbos biomes based on road counts

Blue Cranes were recorded regularly during road counts in only three of the biogeographic areas of the Karoo, the Central Upper, Great and Steytlerville Karoo regions. The species was not encountered during counts in the succulent, Karas, Bushmanland and Noorsveld Karoos, except for one sighting of a pair with a chick in central Bushmanland (30° 25'S, 20° 29'E) on 30 March 1989 (Appendix 3.1). Blue Cranes were common during road counts in the southern Cape but were far less frequently encountered during the Swartland road counts (Appendix 3.1). The number of individual cranes and the number of crane groups recorded per 100 km of road counts in the Central Upper, Great and Steytlerville Karoo regions, the southern Cape and the Swartland are presented in Table 3.2 and Figure 3.4. The mean number of Blue Crane individuals counted in the southern Cape was 15-16 times higher, and the mean number of groups counted was eight times higher, than the means for the three Karoo regions combined. All counts in the southern Cape were higher than all Karoo counts (Appendix 3.1) and these differences were significant for both the number of individuals (U=0, P<0,001, Mann-Whitney U-test) and the number of groups (U=0, P<0,001) counted. Within the Karoo there was no significant difference in the number of individuals recorded per 100 km between the Central Upper, Great and Steytlerville Karoo regions (H=3,5, P>0,05, Kruskal-Wallis Test). The number of groups per 100 km, however, was significantly higher in the Steytlerville Karoo compared with the

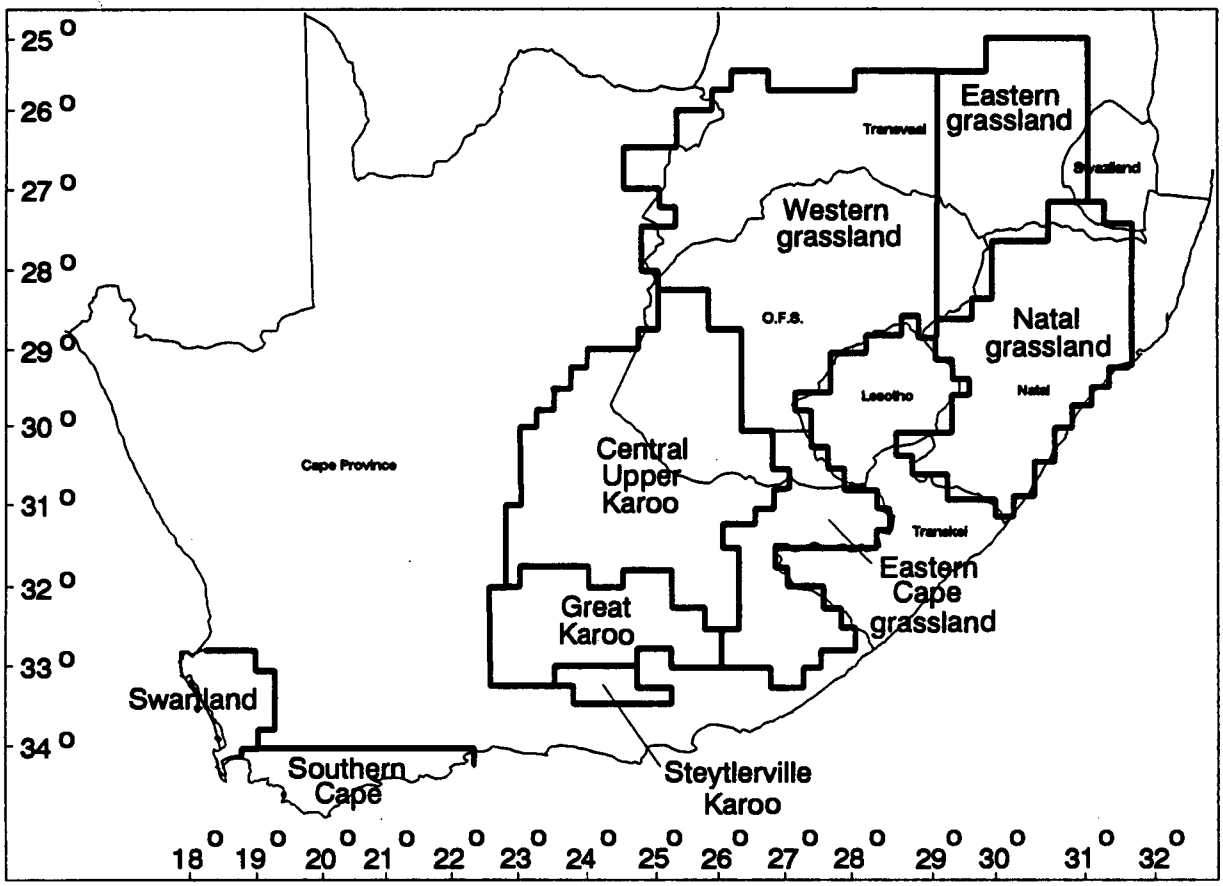

Figure 3.3 The boundaries of the nine regions in South Africa for which reporting rate data for the Blue Crane were amalgamated and compared.

Table 3.1 Details of reporting rates for the Blue Crane in each of nine regions in South Africa. No. sqs - number of grid squares in each region; No. lists - number of checklists from each region; Mean rep. rate - mean reporting rate in each region.

Region	No. sqs	No. lists	Mean rep. rate	S.E.
Eastern grassland	78	6260	19,62	2,44
Natal grassland	113	7565	13,21	1,52
Eastern Cape grassland	63	3455	16,56	2,31
Western grassland	216	21892	5,05	0,63
Central Upper Karoo	170	3998	19,82	1,69
Great Karoo	61	2273	21,99	2,55
Steytlerville Karoo	11	399	24,76	6,48
Southern Cape	30	4261	38,13	3,93
Swartland	19	4077	6,78	1,47

Table 3.2 Details of the number of Blue Crane individuals and groups recorded during road counts in the Central Upper, Great and Steytlerville Karoos, the southern Cape and the Swartland.

Region	No. km	No. inds	Inds/ 100 km	No. groups	Groups/ 100 km
Central Upper Karoo	4608	289	6,3	30	0,7
Great Karoo	2599	52	2,0	12	0,5
Steytlerville Karoo	857	86	10,0	24	2,8
Karoo totals	*8064*	*427*	*5,3*	*66*	*0,8*
Southern Cape	8584	7005	81,6	546	6,4
Swartland	519	12	2,3	4	0,8

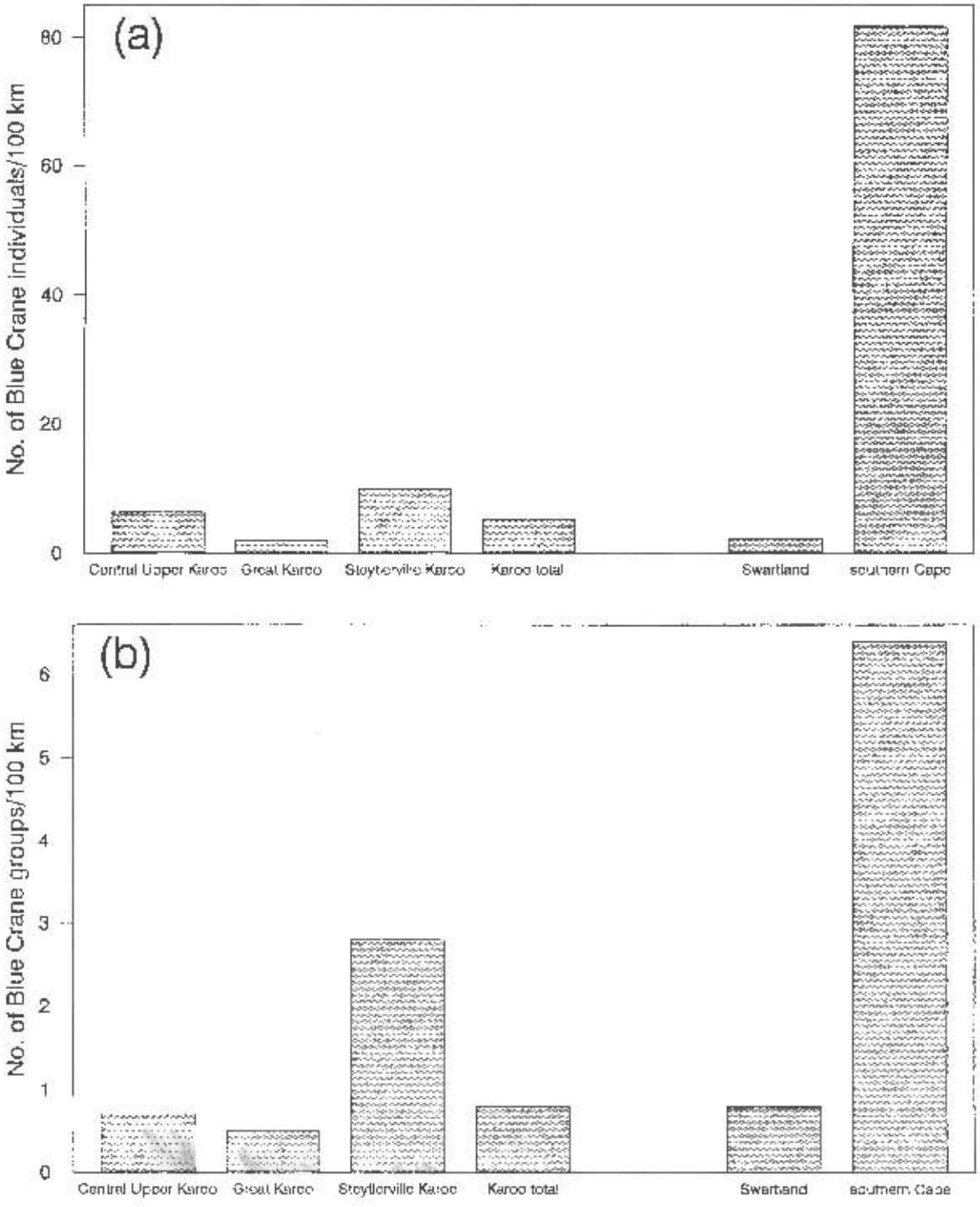

Figure 3.4 The number of Blue Crane individuals (a) and groups (b) counted per 100 km during road transects in the Central Upper, Great and Steytlerville Karoos, the southern Cape and the Swartland.

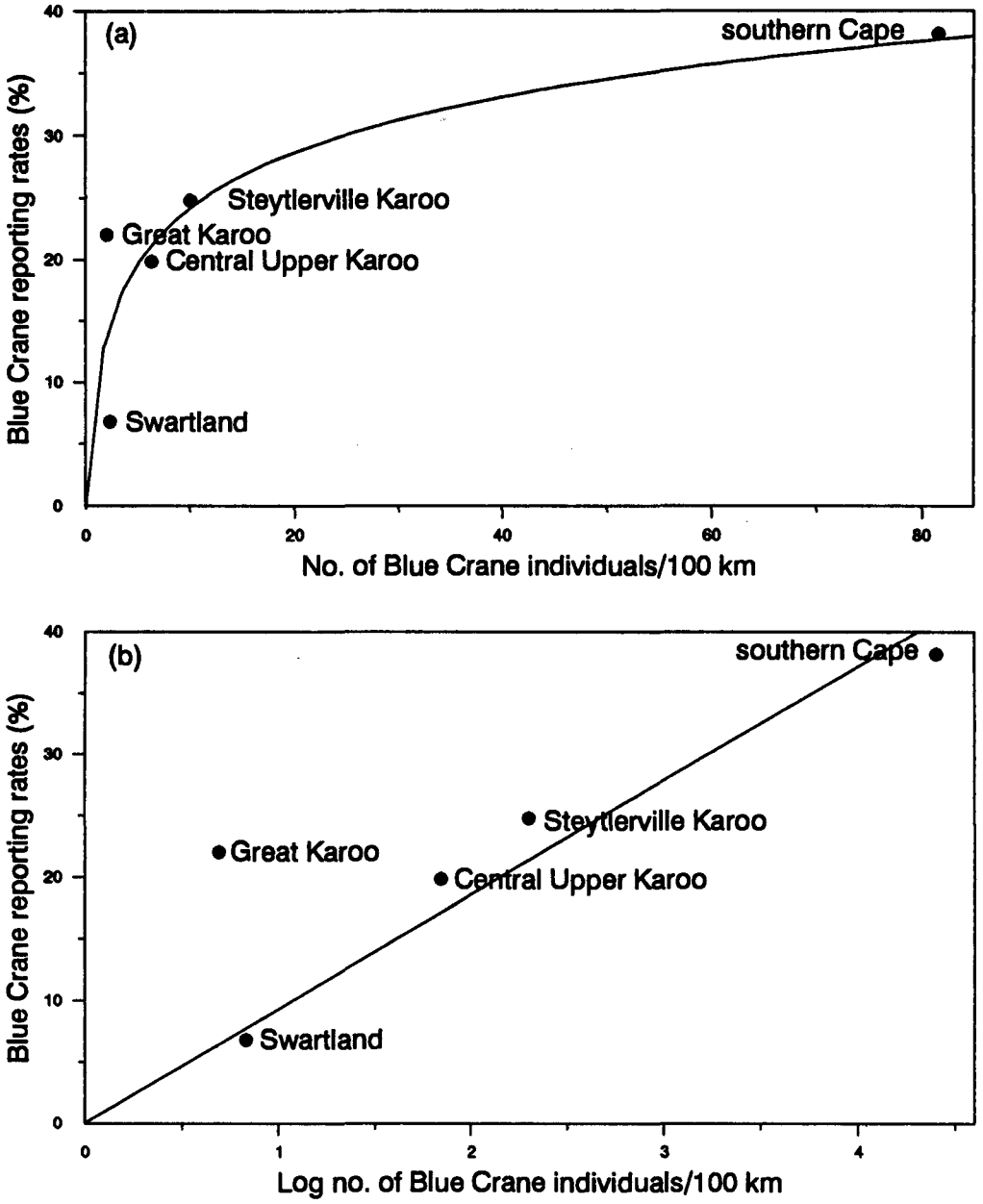

Figure 3.5 The relationship between reporting rate and the number of individuals counted per 100 km of road counts for the Blue Crane in five regions of South Africa. Untransformed data are shown in (a) and in (b) the x-axis has been log transformed. In (b) the line has been fitted by eye and disregards the data point for the Great Karoo.

(5,1 groups/ 100 km), but this difference was not significant (U=10, P>0,05, Mann-Whitney U-test).

During the course of fieldwork, it was thought that Blue Cranes were more visible during the winter due to the nature of the background vegetation. In winter the vegetation in the study area appears uniformly short and bright green, whereas in the summer it appears more heterogenous in height and coloured in various shades of (dry) brown. If the cranes were more visible in winter this should be reflected in a larger mean perpendicular distance (hereafter referred to as the 'distance') to sightings during this period compared with the summer. However, there was no significant difference between mean distances in the summer and winter (summer mean=317 m, S.D.=261 m, n=215; winter mean=307 m, S.D.=241 m, n=214; z=0,28, P>0,05, data normalized by log transformation). It would appear, therefore, that Blue Cranes were equally visible during the two seasons in the southern Cape study area. Even if such a difference exists, it would not affect the densities as calculated using program 'TRANSECT' as this program accounts for such variation (Burnham *et al.* 1980).

The mean sighting distance to small groups of Blue Cranes (1-4 birds) was significantly smaller than the mean distance to large groups (10+ birds). The mean sighting distance to small groups was over 100 m shorter (300 m, S.D=263 m, n=334) than that to large groups (411 m, S.D.=350 m, n=74; z=3,37, P<0.01, data normalized by log transformation). This suggests that small groups of cranes are less visible than large groups.

The distribution of distances is shown in Figure 3.6. The pattern is typical of line transect distance data with relatively few sightings at the shortest distances, increasing rapidly to a peak, and followed by an exponential decrease (with a pronounced 'tail') to the furthest distances (Burnham *et al.* 1980). The paucity of sightings at the shortest distances usually is attributed to study animals fleeing undetected from the observer and only being sighted after they have already moved some distance away. In this study, however, the initial 'trough' in distances probably can be attributed to the cranes avoiding the immediate vicinity of roads. The mean distance of sightings was 331 m (S.D.=294 m, range 0-2500 m, n=470) and the median was 254 m. The peak in distances occurred between about 75-200 m, with the highest proportion at 150-175 m. About half of the sightings (231/470, 49,2%) occurred within 250m, more than three-quarters (386/470, 82,1%) within 500m and virtually all (439/470, 93,4%) within 750 m. Only three sightings (0,6%) were at ranges greater than 1500 m. The cumulative frequency data in Figure 3.6 suggest that the inflection point of sighting distances occurs at about 500-550 m.

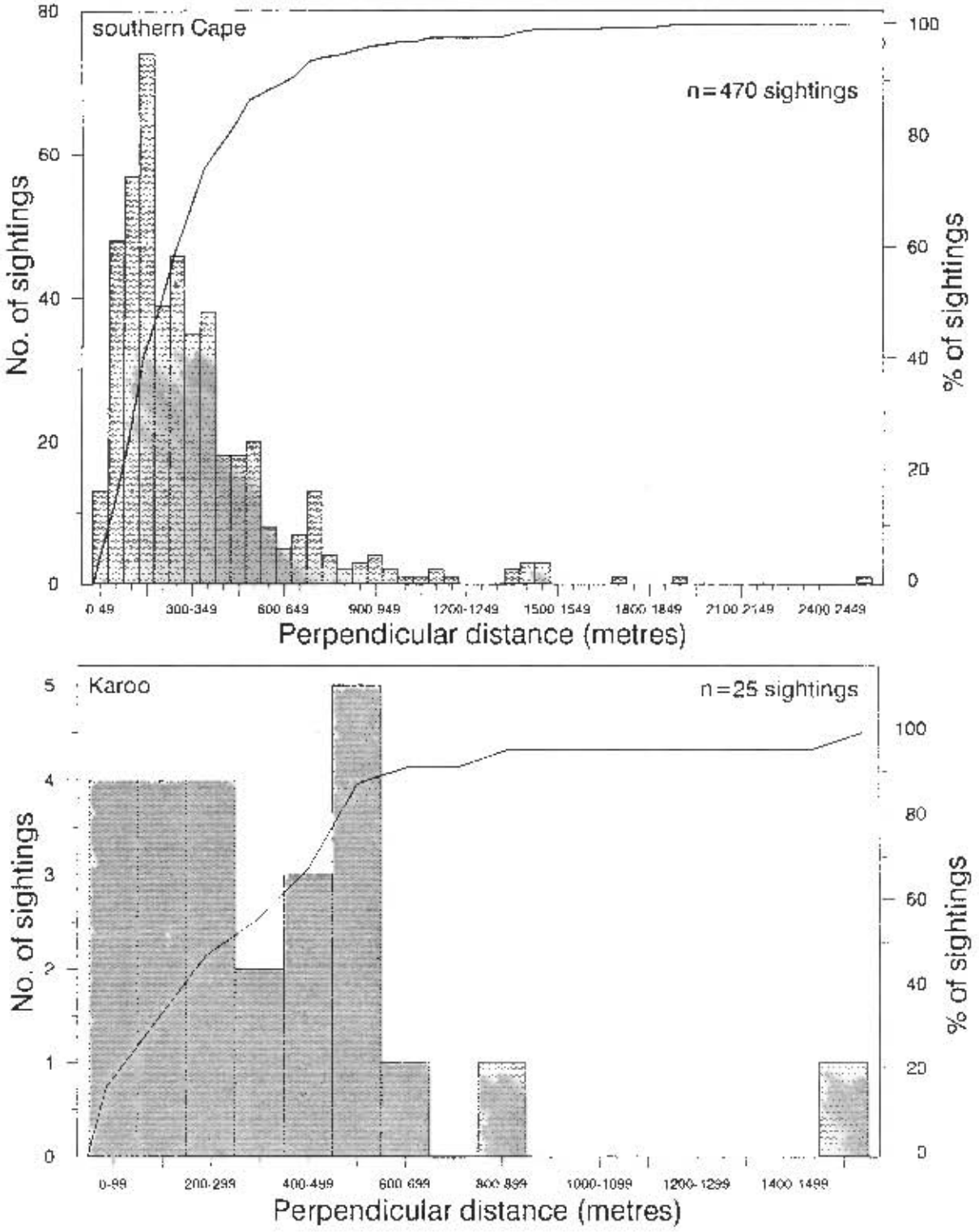

Figure 3.6 The distribution of perpendicular sighting distances to Blue Crane groups seen during line transects in the southern Cape and Karoo regions (bar graphs, left axes) and cumulative frequency graphs of the same data (line graphs, right axes).

Data from aerial censuses made in the southern Cape study area show the same seasonal trend as found during line transects. The January 1986 flight counted 130 Blue Cranes and the July 1986 flight counted 648 cranes. This provides density estimates of 0,22 Blue Cranes/km^2 in January 1986 and 1,12 Blue Cranes/km^2 in July 1986. These translate to total population estimates of 1710 cranes in the southern Cape in January and 8521 cranes in July. The January estimate falls below the 95% confidence limits calculated from the road counts (2400-3700) for the summer but the July estimate falls within the 95% confidence limits for the winter road counts (6150-9550).

Density and total population size in the Karoo and Swartland

It is not possible to apply line transect analyses to the Karoo data as perpendicular distances were only recorded on the final set of transects through this region. Even if distances had been measured on all Karoo transects, however, it is unlikely that sample sizes would have been large enough for meaningful statistical analyses. The distance data from the 25 sightings of Blue Crane groups made during the final transects through the Central Upper, Great and Steytlerville Karoo regions combined are shown in Figure 3.6. The mean distance of sightings in the Karoo (370m, S.D.=311 m, range 2-1500 m, n=25), admittedly based on a small sample, is slightly larger than in the southern Cape (by 39 m) but this difference is not significant ($z=0,34$, $P>0,05$, data normalized by log transformation). This suggests that the species is about equally visible in both areas and therefore that the large differences in abundance between the two regions is due to differences in density rather than conspicuousness. The approximately equal visibility in both regions is not surprizing as both have similar topography and vegetation height. The cumulative frequency data in Figure 3.6 suggest that the inflection point of sighting distances in the Karoo occurs at about 500-600 m.

A crude estimate of the densities and total population sizes of Blue Cranes in the Central Upper, Great and Steytlerville Karoos can be made by interpreting the road counts as simple strip transects and based on the parameters listed below.

1) The data in Figure 3.6 suggest that Blue Cranes beyond 600 m were rarely seen and therefore an effective strip width of 1,2 km (2x600 m) can be used. The associated assumption that all cranes within this distance were seen is unlikely and will result in a conservative estimate of density.

2) The total number of kilometres travelled in the Central Upper, Great and Steytlerville Karoos was 4608 km, 2599 km and 857 km respectively (strip lengths) (Appendix 3.1).

3) The total number of Blue Cranes counted in the Central Upper, Great and Steytlerville Karoo strip transects was 289, 52 and 86 respectively (Appendix 3.1).

4) The total area (in km^2) of suitable Blue Crane habitat in each of the three Karoo regions can be estimated by examining the SABAP distribution map for the species (Figure 2.1, Chapter 2) and calculating the area of that portion of each region where the species occurs. This results in estimates of 92750 km^2 of suitable habitat (of 119 300 km^2) in the Central Upper Karoo, 30250 km^2 (of 46350 km^2) in the Great Karoo, and 5150 km^2 (of 6340 km^2) in the Steytlerville Karoo.

Density (*D*), i.e. the number of Blue Cranes/km^2, can then be estimated for each region as:

$$D = \frac{\text{number of Blue Cranes counted}}{\text{transect length (km) x transect width (km)}}$$

Similarly, the total population size (P) in each region can be estimated as:

$$P = D \times \text{total area suitable habitat } (km^2)$$

The resultant estimates of densities and total population sizes in the three Karoo regions are as follows:

Central Upper Karoo	0,05 cranes/km^2	total pop. - 4848
Great Karoo	0,02 cranes/km^2	total pop. - 504
Steytlerville Karoo	0,08 cranes/km^2	total pop. - 431

The Karoo therefore is estimated (conservatively) to support about 5800 Blue Cranes. It is not possible to present confidence limits to this estimate, however, especially in the light of the high variation in the road counts in the three Karoo regions (Appendix 3.1).

Applying the same methodology to the data from the Swartland, where 7510 km^2 of suitable habitat exists (from Moll & Bossi 1983) and 12 Blue Cranes were seen during 519 km of road counts (strip width of 1,2 km, i.e. 623 km^2 covered), results in a

density estimate of 0,02 Blue Cranes/km^2 and a total population estimate of 145 cranes in this region.

It is not possible to estimate the total population sizes in the grassland regions using the methods above as no road counts or line transects were made in these areas. However, the association shown between measures of relative abundance based on reporting rates and road counts in the fynbos and Karoo regions where data on both parameters are available (Figure 3.5) suggests that tentative estimates of densities and population sizes can be made for these grassland regions based on reporting rates. The logarithmic nature of the association between reporting rates and densities militates for caution when attempting such estimates of density based on reporting rates as relatively small differences in reporting rates between regions may reflect large differences in abundance (Figure 3.5). From Figure 3.5 it can be estimated that the density of Blue Cranes in the western grassland is about 74% of that in the Swartland, i.e. about 0,015 cranes/km^2. Similarly, the density in the Natal grassland is about 65% of that in the Central Upper Karoo, i.e. about 0.03 cranes/km^2. The density in the eastern and eastern Cape grasslands are similar (within 90%) to the density in the Central Upper Karoo, i.e. about 0,05 cranes/km^2. The areas encompassed by these four grassland regions and the total population estimates for each are: eastern grassland - 53510 km^2, 2676 Blue Cranes; Natal grassland - 77520 km^2, 2326 Blue Cranes; eastern Cape grassland - 43220 km^2, 2161 Blue Cranes; and western grassland - 148 180 km^2, 2223 Blue Cranes. The grassland biome therefore supports about 9400 Blue Cranes based on this crude assessment.

Table 3.3 provides a summary of the estimated densities and total population sizes for the nine regions within the range of the Blue Crane in South Africa. The total population estimate for South Africa is 20800 individuals. As only 100-110 individuals are estimated to occur outside of South Africa, in Namibia, Botswana, Lesotho and Swaziland (Chapter 2), South Africa supports over 99% of the estimated world population.

3.5) *Discussion*

The finding that Blue Cranes apparently occur at higher densities and have more than half their total population concentrated outside the grassland biome in the Karoo and fynbos is surprizing as the species traditionally has been associated with grassland regions, e.g. Urban *et al.* (1986). The significance of this finding is discussed further in Chapter 8.

Table 3.3 Summary of estimated densities and total population sizes for the Blue Crane in nine regions of South Africa.

Region	Area (km^2)	Density of Blue Cranes		Estimated total population	
Eastern grassland	53510	0,05		2675	
Natal grassland	77520	0,03		2325	
East. Cape grassland	43220	0,05		2160	
Western grassland	148180	0,015		2225	
Grassland totals	*322 430*			*9385*	
Central Upper Karoo	92750	0,05		4850	
Great Karoo	30250	0,02		505	
Steytlerville Karoo	5150	0,08		430	
Karoo totals	*128 150*			*5785*	
Southern Cape	7640	0,72	(0,40 summer) (1,03 winter)	5450	(3050 summer) (7850 winter)
Swartland	7510	0,02		145	
Fynbos totals	*15150*			*5595*	
TOTAL	***465730***			***20765***	

The positive association between atlas reporting rates and road counts of Blue Cranes in the fynbos and Karoo biomes provides the first indication that the former is a reliable measure of relative abundance. Underhill *et al.* (1992) suggested that the relationship between reporting rate and density is monotonic but not linear and the present study demonstrates that this relationship is indeed logarithmic. This has important consequences for the interpretation of the extent of differences in relative abundance based on bird atlas data.

The reason for the marked difference in Blue Crane abundance between the southern Cape and Swartland regions is obscure. Both regions appear to have superficially similar habitat (see Chapter 6). This dichotomy in patterns of abundance between the western and southern parts of the fynbos biome also is shown by several other large terrestrial birds inhabiting the cereal crop farming areas in the southwestern Cape, i.e. Blackheaded Heron *Ardea melanocephala*, Stanley's Bustard *Neotis denhami*, Karoo Korhaan *Eupodotis vigorsii*, and Black Crow *Corvus capensis* (Hockey *et al.* 1989).

This study presents the first empirically derived estimate of the total population size of the Blue Crane in South Africa. Two previous and subjectively-based estimates were 10000-20000 (Urban 1988) and 5000-10000 (Siegfried 1992). Several estimates of region population sizes in South Africa have been made. Tarboton, Kemp & Kemp (1987) stated the species to be most abundant in the Transvaal in the eastern highveld and estimated the population there at over 1000 individuals. Johnson & Barnes (1986) and Johnson (1992a) counted 1129 Blue Cranes in Natal in 1982 and 109 in 1989 using aerial censuses. The methodology of these censuses, however, was not detailed in their publications and it seems unlikely that coverage was comprehensive. Siegfried (1985) estimated the Cape Province (including East Griqualand, now part of Natal, and Transkei) population at 7000-10000 in the mid-1960s based on unpublished roost counts. Vernon *et al.* (1992) estimated the eastern Cape population at about 7800 birds during the period 1977-1987 but that this total had been reduced to 1000-2000 individuals during the period 1987-1989. They did not, however, provide details of the methods from which these estimates were derived. They defined the 'eastern Cape' as the area lying east of 24° and south of 30° including Transkei but excluding those parts of Lesotho and Natal which fall within this region. This area therefore encompasses all of the eastern Cape grassland and large parts of the Central Upper, Great and Steytlerville Karoos as defined in the present study.

Appendix 3.1 The dates and number of kilometres travelled on the road counts through the various regions of the Karoo and southwestern Cape and the number of Blue Crane individuals and groups counted on each transect.

Region groups	Date	No. km	No. inds	No.
KAROO				
Succulent Karoo				
Western succulent Karoo	Aug. 1988	1442 km	0	0
	Dec. 1988	1444 km	0	0
	Mar. 1989	1472 km	0	0
	Jun. 1989	1476 km	0	0
	Total	**6695 km**	**0**	**0**
Little Karoo	Jun. 1988	262 km	0	0
	Nov. 1988	258 km	0	0
	Mar. 1989	264 km	0	0
	Jul. 1989	259 km	0	0
	Total	**1043 km**	**0**	**0**
Succulent Karoo total		*7738 km*	*0*	*0*
Nama Karoo				
Karas	Aug. 1988	240 km	0	0
	Dec. 1988	237 km	0	0
	Mar. 1989	243 km	0	0
	Jun. 1989	235 km	0	0
	Total	**955 km**	**0**	**0**
Bushmanland	Aug. 1988	701 km	0	0
	Dec. 1988	718 km	0	0
	Mar. 1989	733 km	2	1
	Jun. 1989	716 km	0	0
	Total	**2868 km**	**2**	**1**
Central Upper Karoo	Jul. 1988	1172 km	105	6
	Nov. 1988	1132 km	7	5
	Mar. 1989	1146 km	24	6
	Jul. 1989	1158 km	153	13
	Total	**4608 km**	**289**	**30**
Great Karoo	Jul. 1988	658 km	6	2
	Nov. 1988	647 km	9	5
	Mar. 1989	651 km	30	2
	Jul. 1989	643 km	7	3
	Total	**2599 km**	**52**	**12**

Appendix 3.1 (cont.)

Region groups	Date	No. km	No. inds	No.
Steytlerville Karoo	Jul. 1988	219 km	5	3
	Nov. 1988	211 km	12	6
	Mar. 1989	215 km	16	7
	Jul. 1989	215 km	53	8
	Total	**857 km**	**86**	**24**
Noorsveld Karoo	Jul. 1988	75 km	0	0
	Nov. 1988	70 km	0	0
	Mar. 1989	76 km	0	0
	Jul. 1989	74 km	0	0
	Total	**295 km**	**0**	**0**
Nama Karoo total		*12182 km*	*429*	*67*
SOUTHWESTERN CAPE				
Swartland	Dec. 1991	283 km	0	0
	Jul. 1993	236 km	12	4
	Total	**519 km**	**12**	**4**
Southern Cape	Sep. 1988	483 km	314	30
	Jun. 1989	509 km	568	21
	Jul. 1989	563 km	532	32
	Mar. 1990	576 km	241	25
	Jul. 1990	564 km	760	35
	Nov. 1990	588 km	248	47
	Feb. 1991	583 km	261	38
	May 1991	605 km	599	35
	Jul. 1991	596 km	648	34
	Nov. 1991	584 km	226	37
	Mar. 1992	581 km	227	41
	June 1992	580 km	639	39
	Aug. 1992	591 km	1183	39
	Dec. 1992	593 km	117	52
	Apr. 1993	588 km	442	41
	Total	**8584 km**	**7005**	**546**
Southwestern Cape total		*9103 km*	*7017*	*550*
Karoo & SW Cape Total		**28987 km**	**7446**	**617**

CHAPTER 4

MOVEMENTS OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS* IN SOUTH AFRICA AS ASSESSED BY BIRD ATLAS DATA AND ROAD COUNTS

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SUMMARY

Published comments on the patterns of movements shown by the Blue Crane Anthropoides paradiseus *in South Africa are contradictory. Bird atlas data are unreliable in further elucidating Blue Crane movements. This is due to the confounding effect of seasonal changes in Blue Crane group sizes which are the direct cause of lower reporting rates virtually throughout the range of the species during the winter. Road counts in the fynbos and Karoo biomes show that there is a marked influx into the former region and a possible influx into the latter region during the winter. A comparison between road count data from 1965-1966, which suggest a movement out of the whole Cape Province in the winter, and from 1988-1993, which suggest a movement into the Karoo and fynbos biomes of the province in the winter, suggest a change in the patterns of movements of Blue Cranes between the two periods.*

4.1) *Introduction*

Most cranes (Gruidae) inhabiting temperate regions are strongly migratory, with widely disjunct breeding and wintering ranges (Johnsgard 1983). Tropical species are more sedentary but can show marked local movements and some nomadism, although the extent of these can differ between populations of the same species. For example, a low level of vagrancy has been reported for the Grey Crowned Crane *Balearica regulorum* in South Africa (Geldenhuys 1984, Tarboton 1992a). Many of the Wattled Cranes *Bugeranus carunculatus* breeding in the vast wetland systems of southern Zambia frequently visit the Makgadikgadi wetlands in northern Botswana but the extent of this movement varies between years (Konrad 1981). By contrast, the Transvaal population of this species in South Africa is wholly sedentary (Tarboton 1984). Movements related to drought conditions occur in the Australian Crane *Grus rubicunda* (Blackman 1978, in Johnsgard 1983).

Extreme variation in the extent of migration can occur even in temperate species. For example, the Sandhill Crane *G. canadensis* has some populations which annually migrate over thousands of kilometres between their breeding grounds in the Arctic tundra and the southern United States, while the southernmost breeding populations are entirely sedentary (Drewein & Lewis 1987). Cranes also show adaptability in their patterns of movements in response to man-made influences. These responses include alterations to migratory routes, stopovers and timing (Littlefield 1986, Fulin 1991,

Pogson & Lindstedt 1991, Genard & Lanusse 1992). Eurasian Cranes *G. grus*, which previously wintered largely in northwestern Africa, now spend most of the winter in Spain, due to habitat destruction in the former area and increased cereal farming in the latter region (Alonso, Veiga & Alonso 1987). The Japanese population of the Redcrowned Crane *G. japonensis* has ceased to migrate from the breeding areas in winter, due to the artificial provisioning of food during these months, and is now essentially sedentary (Johnsgard 1983). This represents the most anthropogenically induced alteration of migratory habits by this family.

Aspects of this study were presented in Allan (1992).

4.2) *Aims*

The aims of this study were to:

1) review statements in the published literature on movements of the Blue Crane in South Africa,

2) examine evidence from bird atlas data for seasonal movements by the species,

3) examine information from road counts for seasonal movements in the fynbos and Karoo biomes, and

4) compare the information on movements from bird atlas data and road counts.

4.3) *Methods*

Atlas data on the distribution and reporting rates of Blue Cranes in South Africa were obtained from the Southern African Bird Atlas Project (SABAP, see Chapters 2 and 3). Reporting rates were calculated for the summer (October-March) and winter (May-August) periods in each of nine regions within the South African range of the species (see Figure 3.3 in Chapter 3 for the boundaries of these regions). The reporting rate for each region and season represented the mean of the reporting rates from each square considered individually in that region, and was not based on the percentage of checklists recording the species considering all checklists for the region and season combined. A generalized linear model with a binomial distribution and logistic link function (McCullagh & Nelder 1989) was used to test for significant differences in reporting rates in the regions between the summer and winter periods.

Data from the road counts made in the Karoo and fynbos biomes and described in Chapter 3 were examined for differences in the number of Blue Crane individuals and groups counted during the summer (October-March) and winter (May-August) periods.

4.4) *Results*

Review of literature statements on movements

Seasonal movements by Blue Cranes were first identified by Blaauw (1897, in Walkinshaw 1973), who commented that 'During the annual dry season [winter] this species migrates in some places'. In Natal, Walkinshaw (1963), based on work done in that region in 1962, reported the Blue Crane to be migratory, departing 'northwestward' in March and returning to their breeding grounds in early September. A movement to the northwest in the winter from Natal would mean into the northeastern Orange Free State and southeastern Transvaal. In a later publication (Walkinshaw 1973) he stated the species to be an altitudinal migrant *within* Natal, with birds from the Natal Drakensberg area moving to lower altitudes in March and returning to higher altitudes to breed in September. This would mean a largely easterly and northeasterly movement downwards from the higher-lying western parts of Natal in the autumn (March). Shephard (1962) found that large numbers wintered in the Swartberg area (southwestern Natal, formerly in East Griqualand a part of the Cape Province). West *et al.* (1964) found the species to be resident in the Weenen District in the centre of Natal. Johnson & Barnes (1986), referring to the early 1980s, suggested a northward movement in the winter and a southward movement in the summer within Natal.

In the Transvaal the species is resident but shows local movements leaving the highest plateaus in the eastern grassland during winter (Tarboton, Kemp & Kemp 1987). Observations at one high-lying area in the eastern grasslands (Graskop) confirmed this finding (Urban *et al.* 1986). In the adjacent high-lying areas of Swaziland the species also is a breeding migrant in the summer (Parker in press). The occasional sightings of vagrants in the Transvaal woodland areas north of the grassland biome appear to occur mainly in the winter (see Chapter 2). In the Orange Free State, Geldenhuys (1984), referring to the period 1972-1983, stated the Blue Crane to be 'largely resident' but with 'nomadic local movements'.

In the Cape Province (including East Griqualand, now part of Natal, and Transkei), Siegfried (1985), based on road counts made during 1965-1966, stated the species to move out of the entire region except for East Griqualand in the winter (May-August). By contrast, Vernon *et al.* (1992), referring to the eastern Cape in the 1980s, stated that movements of Blue Cranes in this area were within the Cape Province, with the species migrating to the west from the eastern Cape grasslands into the eastern Cape Karoo during the winter. They defined the 'eastern Cape' as the area lying east of 24° and south of 30°, including Transkei but excluding those parts of Lesotho and Natal which fall within this region. Kieser & Kieser (1978) stated the species to be resident in the De Aar District of the Cape Province within the Karoo biome and Courtnay-Latimer

(1964) found Blue Cranes to be resident in the East London area. Hockey *et al.* (1989) stated the species to be a 'resident and summer visitor' in the southwestern Cape region.

Figure 4.1 summarizes all the above information. It is obvious that many of these literature statements contradict one another and the comment in Urban *et al.* (1986), i.e. that the species is 'Locally migratory but details poorly known', probably best synthesises the current knowledge on the movements of the Blue Crane.

Evidence for seasonal movements based on atlas data

Figures 4.2 and 4.3 show the SABAP distribution and reporting rate maps for the Blue Crane, presented separately for the summer (October-March) and winter (May-August) periods. No clear pattern is obvious from a visual inspection of these maps. Table 4.1 and Figure 4.4 summarize the reporting rate data for each of nine regions within South Africa for the summer and winter periods. Considering the data for all nine regions combined, the winter reporting rate was highly significantly lower than the summer reporting rate ($P<0,001$). Examining the data from each region separately reveals that in eight of the nine regions the same trend was apparent. In two regions (Eastern Cape grassland and southern Cape) the result was significant ($P<0,05$), in three (eastern and Natal grasslands and Great Karoo) it was near significant ($P<0,1$), and in three (western grassland, Central Upper Karoo and Swartland) the result was not significant ($P>0,1$). The only exception to the trend was in the Steytlerville Karoo where the reporting rate was slightly higher in the winter but this result was not significant ($P>0,1$). The number of grid squares covered by the Steytlerville Karoo was relatively small (11 squares) compared with the other regions and therefore this result is based on a small sample size.

Information on seasonal movements based on road count data

Details of the number of Blue Crane individuals and groups counted during road counts in the southern Cape, Swartland, and Central Upper, Great and Steytlerville Karoos presented separately for the summer (November-March) and winter (May-August) periods are given in Table 4.2 and Figure 4.4. More Blue Crane individuals were counted in the Karoo in the winter compared with the summer (8,1 *vs* 2,5 inds/100 km respectively) but this difference was not significant ($U=10$, $P>0,05$, Mann-Whitney U-test). The difference between the number of groups counted in the Karoo in the two seasons (0,9 *vs* 0,8 groups/100 km) also was not significant ($U=18$, $P>0,05$). The number of individuals counted in the southern Cape, however, was significantly higher (123,0 *vs* 37,7 inds/100 km) in the winter than the summer ($U=0$, $P<0.001$). All winter counts were substantially higher than all summer counts (See Appendix 3.1, Chapter 3). Conversely, the number of groups counted in the winter was lower (5,1 *vs*

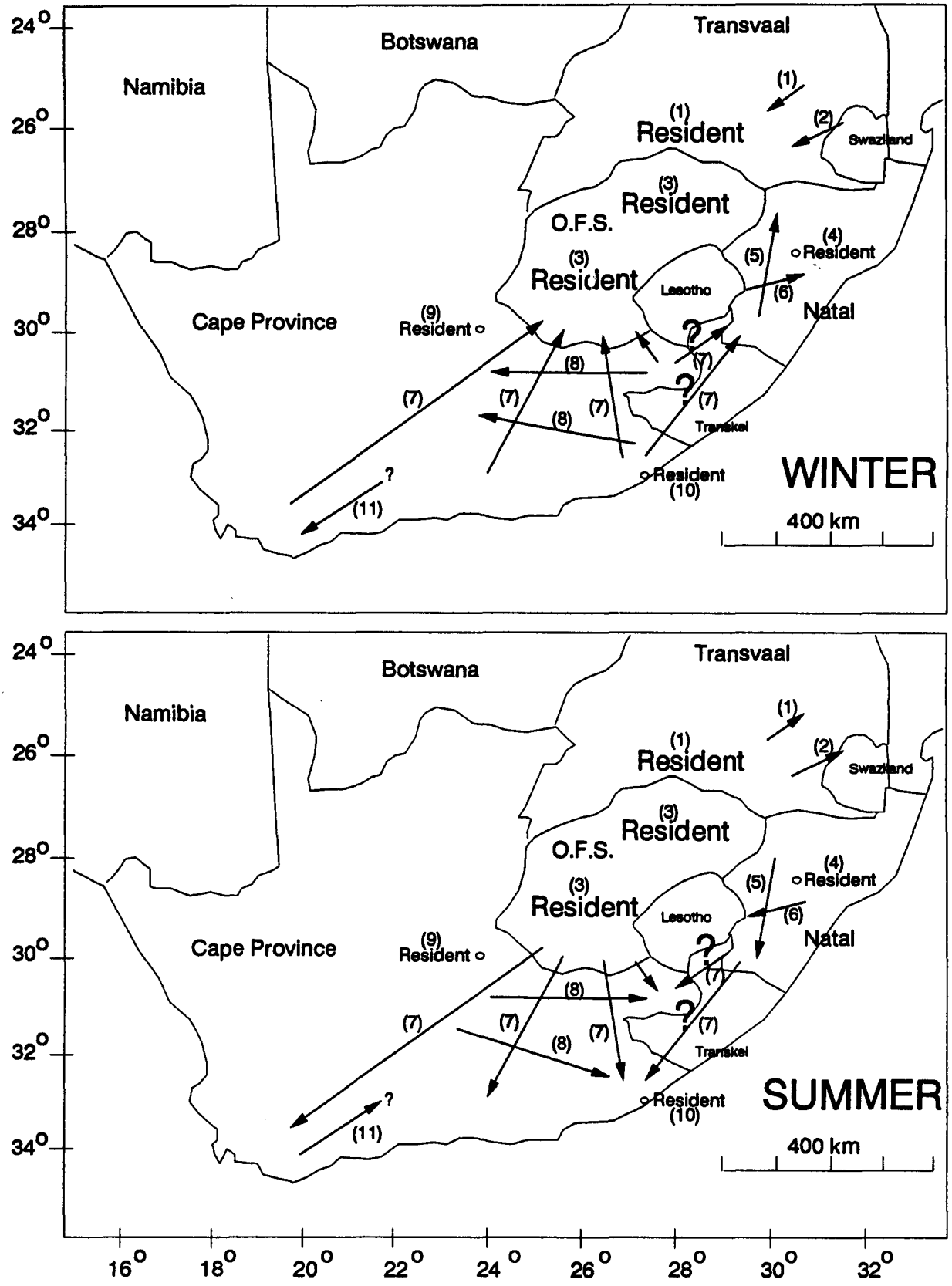

Figure 4.1 Maps summarizing literature statements on patterns of seasonal movements in the winter and summer by Blue Cranes in South Africa. The numbers in parentheses refer to the following references: 1-Tarboton, Kemp & Kemp (1987); 2-Parker (in press); 3-Geldenhuys (1984); 4-West *et al.* (1964); 5-Johnson & Barnes (1986); 6-Walkinshaw (1973); 7-Siegfried (1986); 8-Vernon *et al.* (1992); 9-Kieser & Kieser (1978); 10-Courtney-Latimer (1964); 11-this study.

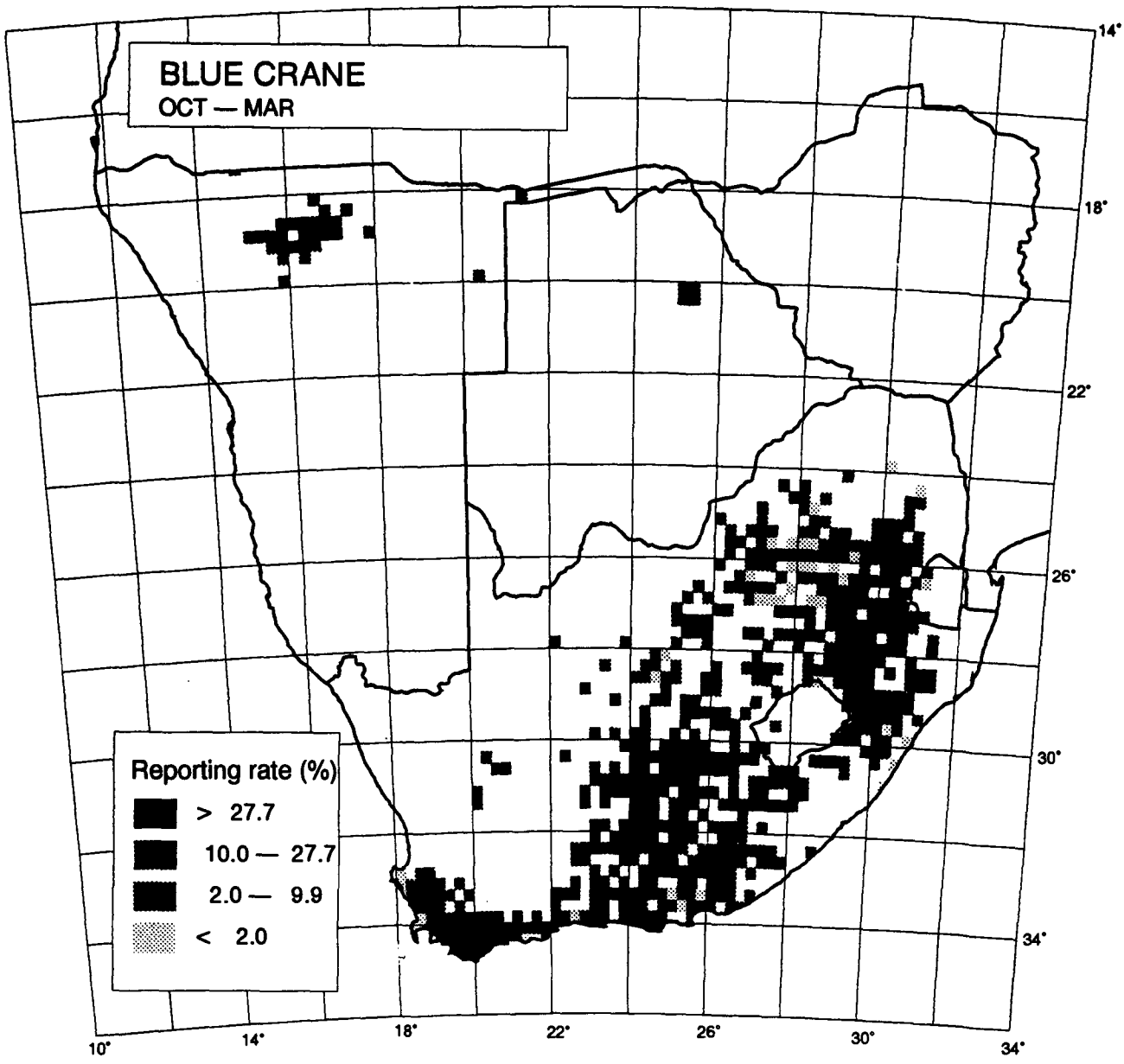

Figure 4.2 The SABAP map of the distribution and reporting rates of Blue Cranes in southern Africa in the summer (October-March).

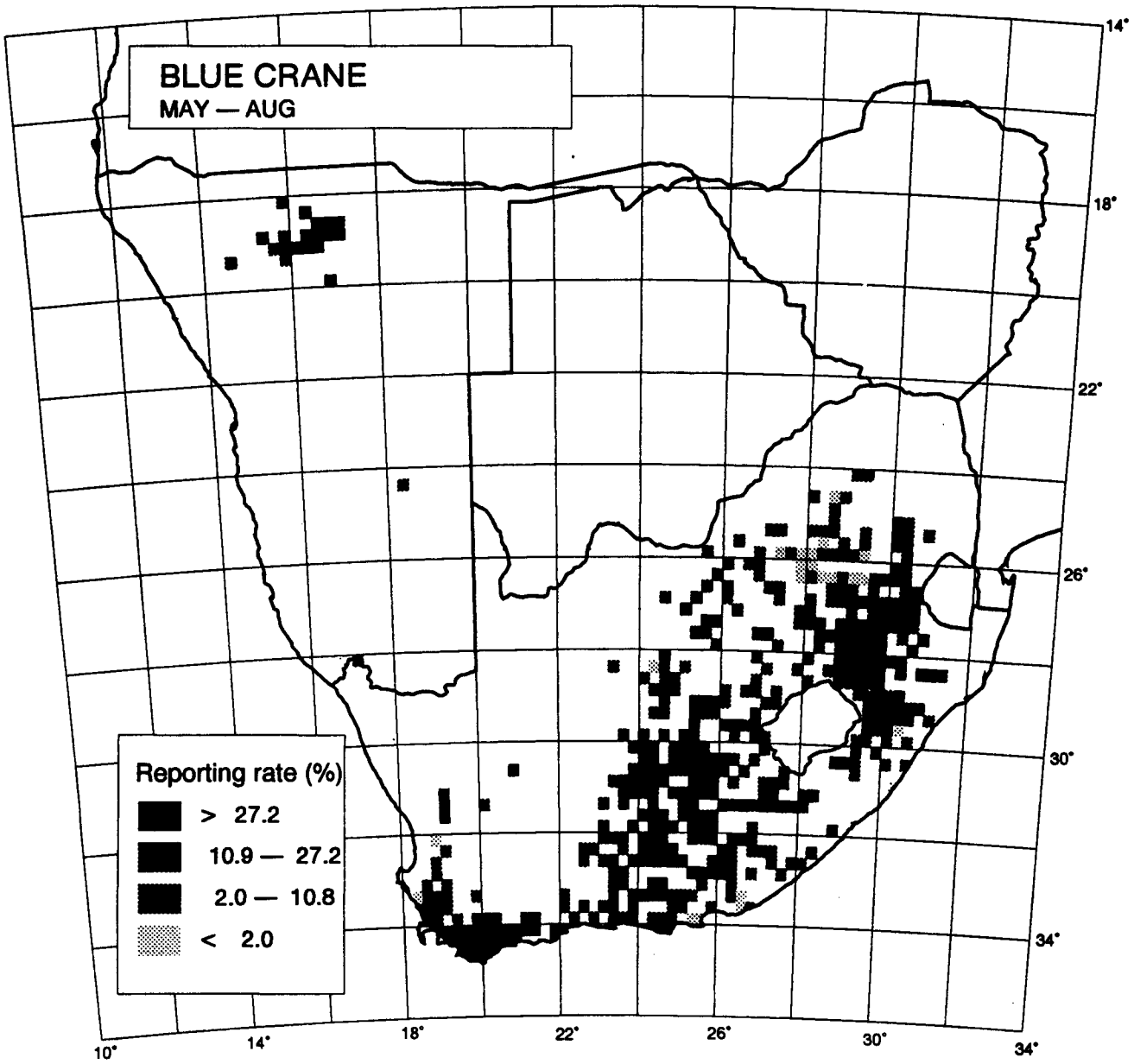

Figure 4.3 The SABAP map of the distribution and reporting rates of Blue Cranes in southern Africa in the winter (May-August).

Table 4.1 SABAP reporting rates for the Blue Crane in nine regions of South Africa for the summer (October-March) and winter (May-August) periods.

Region	Summer	Winter	t	Exact P value	
Western Grassland	5,1%	4,9%	1,41	0,159	n.s.
Eastern Grassland	21,5%	15,8%	1,89	0,059	P<0,1
Natal Grassland	14,5%	10,9%	1,94	0,052	P<0,1
Eastern Cape Grassland	18,2%	13,0%	2,32	0,020	**P<0,05**
Central Upper Karoo	20,1%	17,2%	1,37	0,171	n.s.
Great Karoo	24,8%	15,9%	1,95	0,051	P<0,1
Steytlerville Karoo	24,9%	26,6%	-0,60	0,548	n.s.
Southern Cape	40,2%	30,7%	2,13	0,033	**P<0,05**
Swartland	7,5%	5,9%	0,19	0,849	n.s.
Total	**15,9%**	**12,6%**	**4,42**	**0,000**	**P<0,001**

Table 4.2 The number of Blue Crane individuals and groups counted per 100 km during road counts in the southern Cape, Swartland, and Central Upper, Great and Steytlerville Karoos presented separately for the summer (November-March) and winter (May-August) periods.

Region	Inds/100 km Summer	Inds/100 km Winter	Groups/100 km Summer	Groups/100 km Winter
Southern Cape	37,7	123,0	6,9	5,9
Swartland	0	2,3	0	1,0
Central Upper Karoo	1,4	11,1	0,5	0,8
Great Karoo	3,0	1,0	0,5	0,4
Steytlerville Karoo	6,6	13,4	3,1	2,5
CUK, GK & SK totals	*2,5*	*8,1*	*0,8*	*0,9*

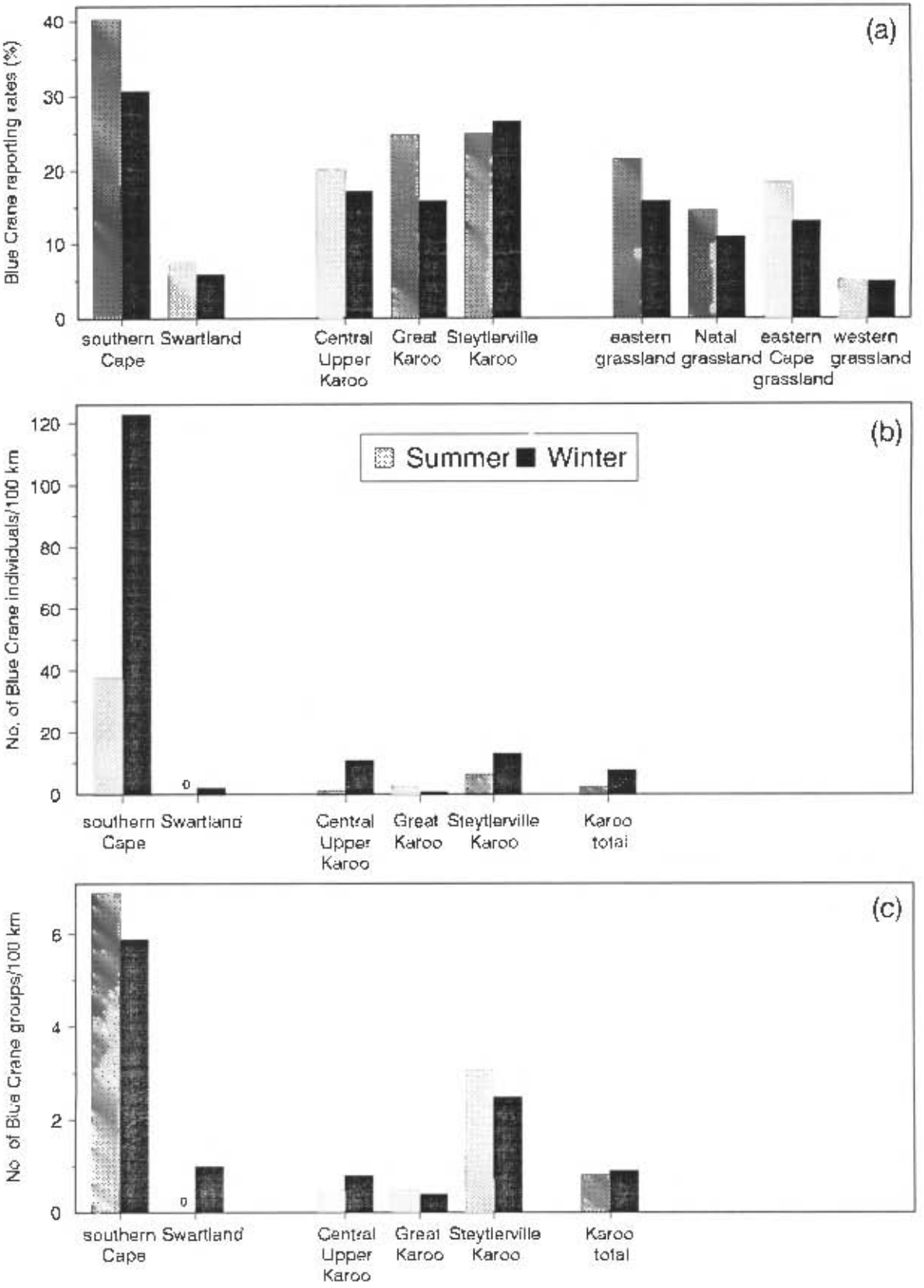

Figure 4.4 Graphs showing the mean reporting rates of Blue Cranes in nine regions of South Africa (a), and the number of Blue Crane individuals (b) and groups (c) counted per 100 km of road counts in the southern Cape, Swartland, and Central Upper, Great and Steytlerville Karoos, presented separately for the summer (October-March) and winter (May-August) periods.

6,9 groups/100 km) than in the summer but this difference was not significant ($U=10$, $P>0,05$). Data from the September 1987 and April 1993 road counts in the southern Cape have been excluded from this analysis as they span transitional periods between summer and winter. Figure 4.5 shows the seasonal variation in individuals and groups counted per 100 km in the southern Cape in more detail (and includes the September 1987 and April 1993 data). Twelve Blue Cranes in five groups were seen during the single winter road count through the Swartland but none were recorded there during the single summer road count.

Subjecting the road count data from the southern Cape to line transect analysis (see Chapter 3) confirmed the pattern of seasonality in this region. This confirmation is particularly persuasive as estimates of density based on line transect methodology are not affected by any seasonal change in the conspicuousness of the study animal (Burnham *et al.* 1980). Information from the two aerial censusses in the southern Cape (see Chapter 3) further reinforced the pattern of a marked winter increase observed during road counts.

4.5) *Discussion*

The atlas data suggest a seasonal reduction in Blue Crane numbers throughout their South African range during the winter. This unlikely scenario is at odds with the patterns suggested by the road count data. The latter suggest a possible increase in the winter in the Swartland and Karoo, although the results for these areas were not significant. The road count, line transect and aerial census data for the southern Cape show an unequivocal winter increase in this region. This is particularly perplexing as the atlas data for this region revealed a significant drop in reporting rates during the winter. Any temporal change in Blue Crane migration patterns can be ruled out as a possible explanation as the atlas, road count and other data were collected contemporaneously in this, and the other, regions (see Chapters 2 and 3).

The explanation for this apparent paradox comes from unrelated work done in the Kalahari Gemsbok National Park, South Africa during August 1992. While conducting fieldwork for SABAP the author compiled 21 bird checklists for grid squares in the Park while at the same time counting the total number of individuals of each species of bird encountered. Figure 4.6 shows the reporting rate relative to the number of individuals counted for each of the 88 species recorded during that study. These data are presented separately for species found solitarily or in pairs *versus* those found in flocks of three or more birds. The interesting feature is that species found in flocks had relatively lower reporting rates relative to the total number of individuals counted when compared with species found solitarily or in pairs. The localization of the population into isolated flocks results in lower reporting rates compared with dispersed populations due to the

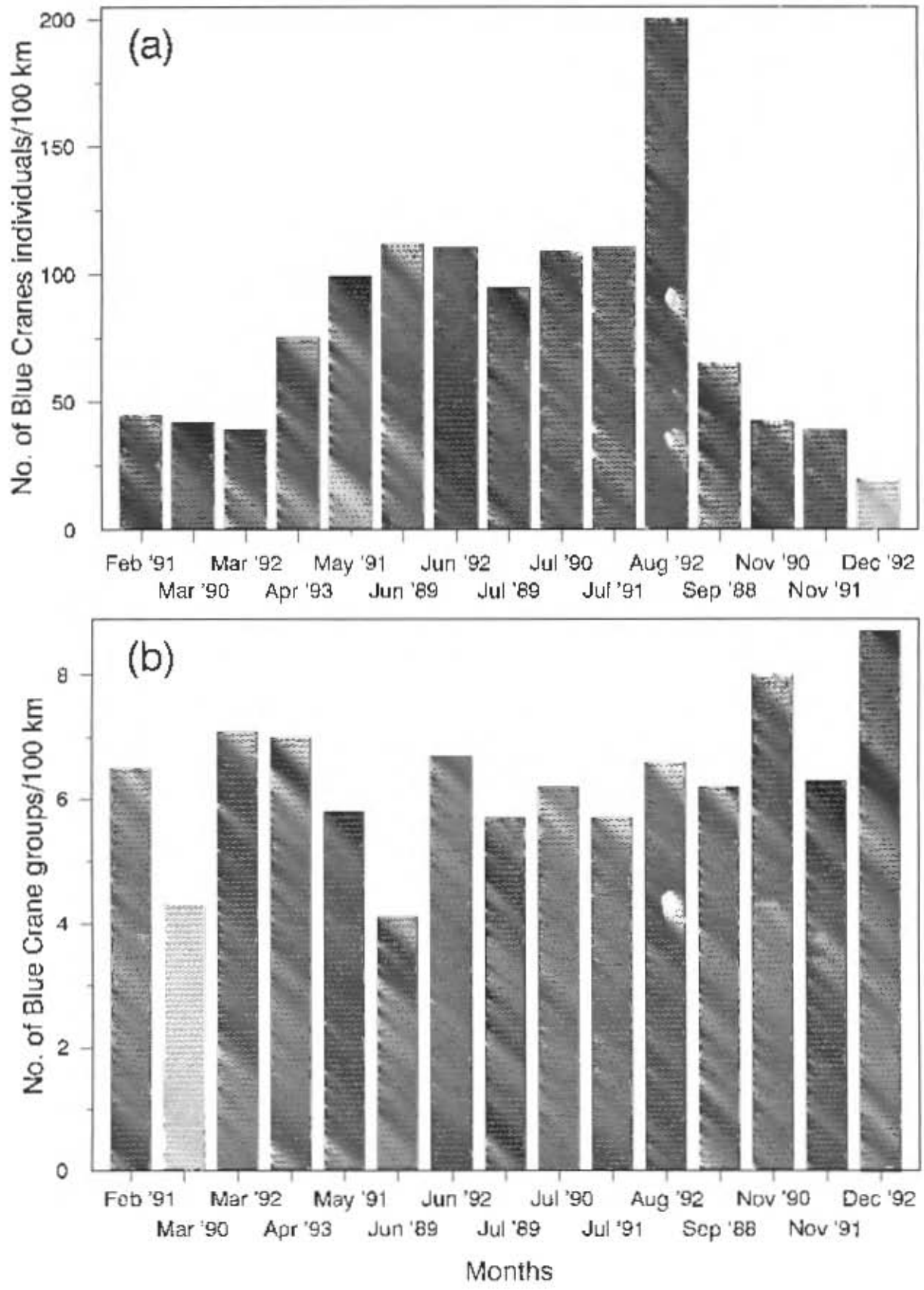

Figure 4.5 The number of Blue Crane individuals (a) and groups (b) counted per 100 km of road counts in the southern Cape presented by months.

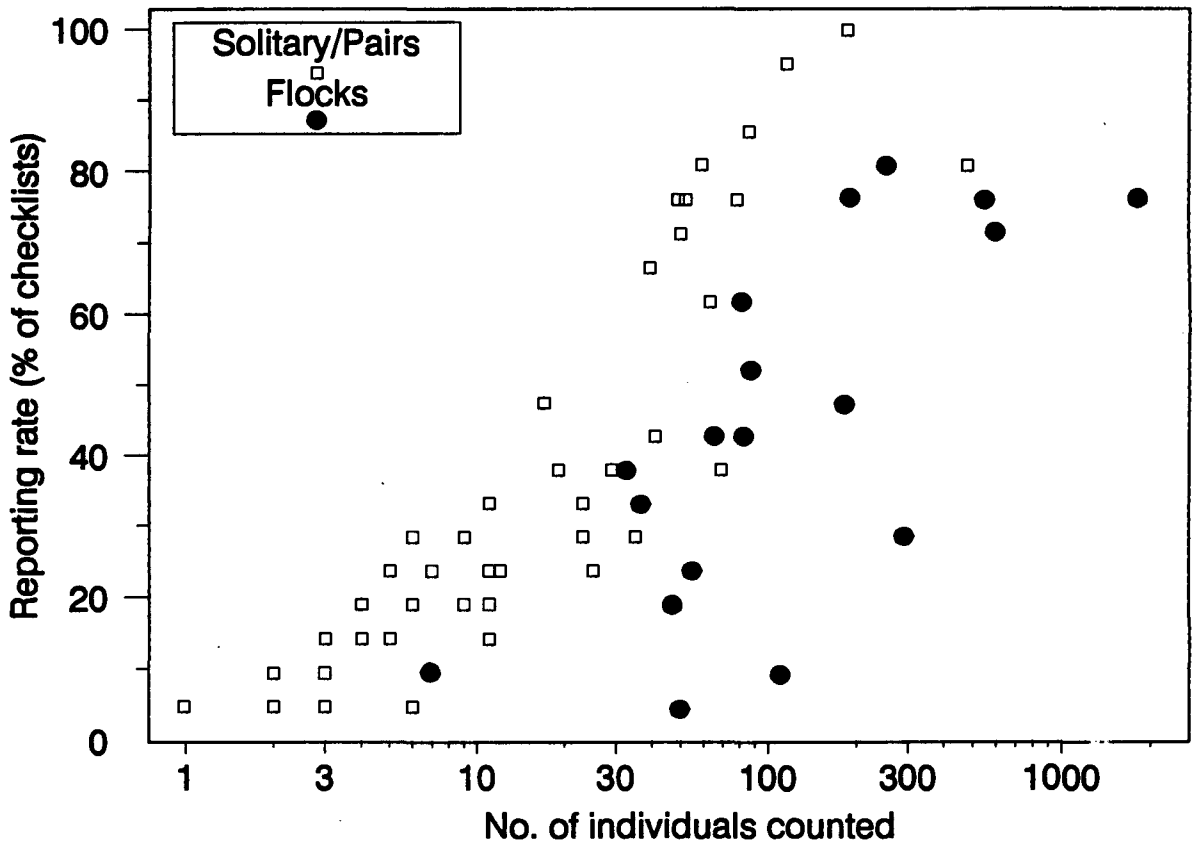

Figure 4.6 The relationship between reporting rate (as calculated from 21 checklists) and the number of individuals counted for 88 bird species in the Kalahari Gemsbok National Park during August 1992. Data presented separately for species found solitarily or in pairs *versus* those found in flocks of three or more birds. Note that the x-axis has been logged.

increased chance of not encountering a flock during atlassing. Actual censuses (e.g. road counts) are not subject to this bias as the large number of individuals included in the count when the relatively few large flocks are encountered compensates for the localized flocks not encountered while censusing these species. It follows that if a species forms large flocks at one time of the year but disperses into smaller groups at other times of the year, the reporting rate of that species would change without any movements by the species being implicated. This is what probably occurs in the Blue Crane. The overall lower reporting rate in the winter probably is due to the localization of the population into large winter flocks during this period. This effect apparently obscures any pattern in reporting rates resulting from seasonal movements by the species. The strength of this effect is apparent from the southern Cape data, where the reporting rate significantly decreased in the face of a significant increase in the density of the species during the winter in this region.

Table 4.3 presents data confirming the seasonal change in Blue Crane mean group sizes between the summer (October-March) and winter (May-August) periods in various regions of South Africa. Only the data from the present study can be tested statistically. Mean group sizes in the summer were significantly lower than in the winter in both the Karoo (3,2 *vs* 9,2 cranes/group; F=2,74, 35 and 30 degrees of freedom, P<0,01, F-test) and the southern Cape (5,6 *vs* 21,2 cranes/group; F=2,86, 233 and 238 degrees of freedom, P<0,001; only group size data from the road counts used).

Further confirmation of the effect of group size changes in explaining the discrepancy between the reporting rate and road count data would come from a seasonal difference in the number of groups actually encountered during the road counts. The expectation would be that fewer groups would have been encountered during the winter counts. There was no significant difference (see above), however, between the number of groups counted in the summer and winter in the Karoo and southern Cape. This is not surprizing as a large sample size would be necessary to demonstrate such an effect. The limited Karoo road count data are unsuitable for this purpose. The larger southern Cape dataset shows a trend towards fewer groups being seen during the winter compared with the summer (6,9 *vs* 5,1 groups/100 km respectively).

This novel finding that seasonal changes in group size in birds can result in changes in reporting rates unrelated to movements has profound significance for the interpretation of avian atlas data. Underhill *et al.* (1992) provide an excellent example of the value of seasonal analyses based on reporting rates (and discuss other *caveats* to the use of reporting rates). The results presented here should not be interpreted as a blanket negation of the value of reporting rates in identifying patterns of seasonal movements. They provide yet another *caveat* to the interpretation of such data, namely that seasonal changes in reporting rates should be interpreted cautiously in species which

Table 4.3 The seasonal change in Blue Crane group sizes between the summer (October-March) and winter (May-August) periods in various regions of South Africa.

Region	Mean group size summer	Mean group size winter	Source
South Africa	**3,9** (n=578 grps)	**22,2** (n=62 grps)	Filmer & Holtshausen (1992)
Eastern Cape Karoo & grassland	**10,0** (n=131 grps)	**23,5** (n=148 grps)	Vernon *et al.* (1992)
Karoo	**3,2** (n=31grps)	**9,2** (n=36 grps))	this study*
Southern Cape	**5,6** (n=239 grps)	**21,2** (n=234 grps)	this study**

* - *P<0,01*
** - *P<0,001*

show seasonal differences in their social structure or other factors which might affect their conspicuousness to atlas observers. Wherever possible, independent data should be provided to test interpretations based on reporting rates.

The information presented in this study provide few insights into seasonal movements by Blue Cranes in South Africa. The road count data from the Karoo are equivocal but suggest a possible movement into this biome during the winter. This agrees with the findings of Vernon *et al.* (1992) who suggested that the eastern Cape grassland breeding population winters in the Karoo. The road count and aerial census data also show an obvious winter movement into the southern Cape region and this probably also applies to the nearby Swartland. The origin of these birds, however, is obscure.

The finding that Blue Cranes apparently increase in the winter in the Karoo, southern Cape and Swartland is directly contradictory to the findings of Siegfried (1985) who suggested that the species moves out of all these regions (and presumably northwards into the grassland biome) during the winter. His suggestion, however, is based on changes in the number of Blue Cranes groups encountered during his road counts in the summer and winter periods, i.e. fewer groups encountered in the winter. This approach is flawed as it does not take into account changes in group size between the two periods, i.e. fewer groups may have been encountered in the winter but this could have been compensated for by larger group sizes. Examining his published data (his Table 1) for the actual numbers of birds, as opposed to numbers of groups, counted, however, reveals that fewer birds also were counted in the winter *versus* the summer in all of his regions which lie within the current boundaries of the Cape Province. About 42 Blue Cranes/5000 km were counted in the summer and about 11/5000 km in the winter (these data do not lend themselves to statistical testing). This suggests that the patterns of movements of Blue Cranes in the Cape Province have changed between the periods 1965-1966 and 1988-1993. Another aspect of the status of the species in the Cape Province that has changed between these two periods is identified in Chapter 8, i.e. a dramatic increase in the density of the southern Cape population.

What is clear from this study is that the Blue Crane is a partial migrant and that some birds are found throughout its South African range throughout the year (see Figures 4.2 and 4.3). Clearly more research into the movements of the species is required and should involve more sophisticated methods than those presented here. An extensive colour-ringing project and the use of satellite tracking are to be especially recommended.

CHAPTER 5

POPULATION STRUCTURE AND BREEDING HABITS OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS* IN THE SOUTHWESTERN CAPE AND THE KAROO

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SUMMARY

The mean group size of Blue Cranes Anthropoides paradiseus *in the Karoo was smaller than in the southwestern Cape. The median and modal group size in both regions, however, was two. Although groups of one to four birds comprised the most frequent group sizes, the majority of cranes were found in larger groups. Mean group sizes in both regions were smaller in summer than in winter. Mean flock sizes also were smaller in the summer in the southwestern Cape. The proportion of breeding pairs relative to the total adult population was 28% in the southwestern Cape and 47% in the Karoo. Only a minority of breeding pairs (25-33%) joined flocks in the winter. Egg-laying was earlier in the southwestern Cape than in the grassland biome. There was a dichotomy in the choice of nest sites between the southwestern Cape and the grassland biome. In the former region most nests were in agricultural fields or cultivated pastures and were distant from wetlands. In the grassland biome most nests were in natural grassland and were associated with wetlands. The most commonly recorded nest material was vegetation, followed by small stones and mammal faeces. Only a minority of nests had no nest material. The usual clutch size was two eggs. The mean unfledged brood size (1,6) was larger than the mean fledged brood size (1,3). One brood apparently containing three fledged young was recorded. The proportion of pairs with fledged young in the post-breeding period was 58% and was similar in the Karoo and southwestern Cape. The percentage of juveniles in the population in the post-breeding period was 9-12% in the southwestern Cape and 14-17% in the Karoo. In the southwestern Cape, reproductive success during the breeding seasons of 1991-1992 and 1992-1993 apparently was higher than during the previous two seasons.*

5.1) *Introduction*

Individuals of all species of cranes, including the Blue Crane *Anthropoides paradiseus*, rarely are found alone. Mated pairs remain together throughout the year, often accompanied by one or two juveniles from their previous breeding attempt (e.g. Tarboton, Barnes & Johnson 1987). The juvenile dependence period is protracted and young usually stay with their parents throughout most of the first year of their lives (e.g. Tacha 1988). Juveniles can be distinguished from adults by subtle differences in plumage and soft-part coloration (e.g. Lewis 1979a). Many mated pairs and families

join flocks of conspecifics during the non-breeding period (e.g. Nesbitt & Williams 1990) but even within these flocks, pairs and families remain in close proximity (e.g. Tacha & Vohs 1984). Flocks of cranes, however, can be found at all times of the year (e.g. Tarboton 1992a). Individuals in flocks in the breeding season presumably comprise pairs that are not breeding or already have failed in that season, and unmated birds. The age of first breeding in cranes is two to six years (Cramp & Simmons 1980, Nesbitt & Wenner 1987, Nesbitt 1989, Tacha *et al.* 1989, Nesbitt 1992), and therefore many cranes in flocks probably are unmated birds. In most cranes, including the Blue Crane, only two age classes can be identified in the field, juveniles (first year) and adults. The proportion of birds occurring as non-breeders in flocks during the breeding season can be relatively high, indeed frequently over 50% (e.g. Melvin *et al.* 1990, Tarboton 1992a)

Most cranes breed in wetlands, but two species, the Blue and Demoiselle *A. virgo* Cranes, breed in dryland habitats (Johnsgard 1983). The breeding biology of wild Blue Cranes has not been investigated in detail, except for one study in Natal (Walkinshaw 1963). Additional information on nest sites, breeding seasons, clutch sizes, hatching success and brood sizes in Blue Cranes is presented by Walkinshaw (1973), Geldenhuys (1984), Maclean (1993), Siegfried (1985), Tarboton, Kemp & Kemp (1987), Brown (1992a), Filmer & Holtshausen (1992), and Vernon *et al* (1992).

The proportion of juvenile (post-fledging) cranes in the population, as assessed during the post-breeding period, has been used to estimate the breeding productivity of many crane species (e.g. Miller & Hatfield 1974). These data also have been used as a basis for assessing the conservation status of cranes. For example, Archibald *et al.* (1981) state that healthy populations of cranes should have about 10-15% juveniles in the post-breeding period. This study presents the first data on age ratios in Blue Cranes.

5.2) *Aims*

The aims of this study on the Blue Crane in the southwestern Cape and the Karoo were to examine:

1) the population structure of the species, including group sizes and the relative proportions of breeding pairs, non-breeding birds and juveniles, and

2) the breeding habits of this crane, including egg-laying periods, nest sites, clutch and brood sizes, and the proportion of breeding pairs with fledged young in the post-breeding period.

5.3) *Study areas and methods*

Most of the observations on Blue Cranes used in this study were collected during road counts in the southwestern Cape and Karoo made between 1988 and 1993. Details

of these counts are given in Chapter 3. The methods employed during all of the counts were similar. The vehicle was stopped briefly when cranes were seen and details of the time of day, locality, group size, age classes, activity, and habitat were recorded. During the stop, all cranes visible in the area were considered as part of the same group even if they were relatively widely dispersed. The same details were recorded for cranes seen at other times so that these additional data could be incorporated in the study where relevant.

In assessing group sizes of cranes, chicks, i.e. less than full size and incapable of proper flight, were disregarded. Data on chicks, however, were used in assessing brood sizes, breeding seasons, etc. Two age classes of fully grown cranes were discernable, adults and juveniles. Juveniles, i.e. fully grown and capable of flying but less than 12 months old, were distinguished from 'adults' (i.e. over 12 months old) by their less 'bulbous' head shape, uniformly coloured heads (adults have a pale crown), brownish tinge to their upperparts and, especially, their lack of elongated inner tertials (Urban *et al.* 1986, pers. obs). In discussing group sizes the following terminology is used: 'singletons' refers to sightings of single adult cranes (juveniles were never seen alone), 'pairs' to two adult cranes, 'families' to two adults with one or two juveniles (or chicks), and 'flocks' to aggregations containing more than two *adult* cranes. The term 'group' refers to all four of these combinations.

Details were recorded of all breeding Blue Cranes seen with eggs, unfledged chicks and fledged juveniles during road counts and at other times. These details included: date, locality, habitat, proximity to wetlands, nest structure, clutch size, and brood size and age. Forty-three nests with eggs were recorded (southwestern Cape - 32, Transvaal grassland - 10, Karoo - 1), 52 pairs with unfledged chicks (southwestern Cape - 34, Transvaal grassland - 8, Karoo - 10) and 281 pairs with fledged juveniles (southwestern Cape - 253, Transvaal grassland - 5, Karoo - 23). These data were collected during the period 1982-1993 (southwestern Cape -1990-1993, Transvaal grassland - 1982-1990, Karoo - 1987-1991). The micro-structure of nineteen nest sites with eggs in the southwestern Cape was examined from photographs taken of these sites. Additional information on breeding in South Africa was obtained from the nest record card collection of the Southern African Ornithological Society (SAOS NRCs), which provided 161 breeding records (southwestern Cape - 47, grassland biome - 98, Karoo - 16), and the Cape Nature Conservation data bank, which provided 19 records of brood sizes in the southwestern Cape.

5.4) *Results*

Group sizes

The mean group size in the Karoo (5,7, S.D.=9,6, range=1-63, n=92) was significantly smaller than in the southern Cape (12,6, S.D.=32,9, range=1-309, n=592; F=1,74, d.f. = 591 and 91, $P<0,01$, F-test). The median and modal group size in both regions, however, was two. Although the smaller group sizes (one to four) were the most common, the majority of birds occurred in groups larger than this (Table 5.1, Figure 5.1). In the Karoo, groups of between one and four birds comprised 78,3% of groups (72/92) but 70,0% of birds (366/523) occurred in groups larger than this. In the southern Cape, groups of between one and four birds comprised 73,7% of groups (436/592) but 86,9% of birds (6495/7474) occurred in groups larger than this.

The mean flock size in the Karoo (17,6, S.D.=14,9, range=4-63, n=21) was smaller than in the southern Cape (33,8, S.D.=51,3, range=3-309, n=194) but this difference was not significant (t=0,6, d.f.=213, $P>0,05$, t-test).

Mean group sizes in the summer (November-March) were significantly smaller than in the winter (May-August) in both the Karoo (summer-3,4, S.D.=5,5, range=1-31, n=52; winter-8,7, S.D.=12,6, range=1-63, n=40; F=2,48, d.f. = 39 and 51, $P<0,01$, F-test) and the southern Cape (summer-5,4, S.D.=14,9, range=1-129, n=259; winter-20,3; S.D.=44,0, range=1-309, n=261; F=2,78, d.f. = 260 and 258, $P<0,01$, F-test).

The mean flock size in the southern Cape also was significantly smaller in the summer (19,0, S.D.=30,3, range=3-129, n=50) than the winter (43,9, S.D.=59,2, range=3-309, n=113; z=4.19, $P<0,01$, z test). Data on mean flock sizes in the Karoo were meagre (summer-15,8, S.D.=12,8, range=4-31, n=5; winter-18,2, S.D.=15,8, range=5-63, n=16) and showed no significant difference between the summer and winter (U=36,5, $P>0,05$, Mann-Whitney U-test).

Table 5.2 and Figure 5.2 show the number and percentage of Blue Crane adults found as singletons, in pairs and in flocks in the southern Cape by months. Table 5.3 provides the same data for the Karoo by seasons (summer, i.e. November-March, and winter, i.e. May-August). The overall proportion of adult cranes seen as singletons in both regions was small (0,8% in the southern Cape and 2,5% in the Karoo) and was slightly higher in the summer than in the winter. The overall proportion of adult birds found in pairs in both regions also was small but significantly higher in the Karoo (southern Cape-10,9%, Karoo-24,0%; χ^2=76,8, $P<0,001$, d.f.=1). A significantly higher proportion of pairs was found in both regions during the summer (southern Cape summer-27,8%, winter-6,0%; Karoo summer-46,9%, winter-12,4%). Road count data from the southern Cape, however, suggest that a large amount of the increase in the relative proportion of adult cranes found in pairs in the summer in this region was due

Table 5.1 Summary of group size structure of Blue Cranes in the Karoo and southern Cape.

	Karoo				Southern Cape			
Grp size	No. of grps	% of grps	No. of inds	% of inds	No. of grps	% of grps	No. of inds	% of inds
1	11	12,0%	11	2,1%	55	9,3%	55	0,7%
2	41	44,5%	82	15,7%	262	44,2%	524	7,0%
3	16	17,4%	48	9,2%	76	12,8%	228	3,1%
4	4	4,3%	16	3,1%	43	7,3%	172	2,3%
5-10	9	9,8%	58	11,1%	48	8,1%	327	4,4%
11-20	3	3,3%	44	8,4%	35	5,9%	517	6,9%
21-50	7	7,6%	201	38,4%	33	5,6%	1070	14,3%
51-100	1	1,1%	63	12,0%	23	3,9%	1641	22,0%
100+	-	-	-	-	17	2,9%	2940	39,3%
Total	92		523		592		7474	

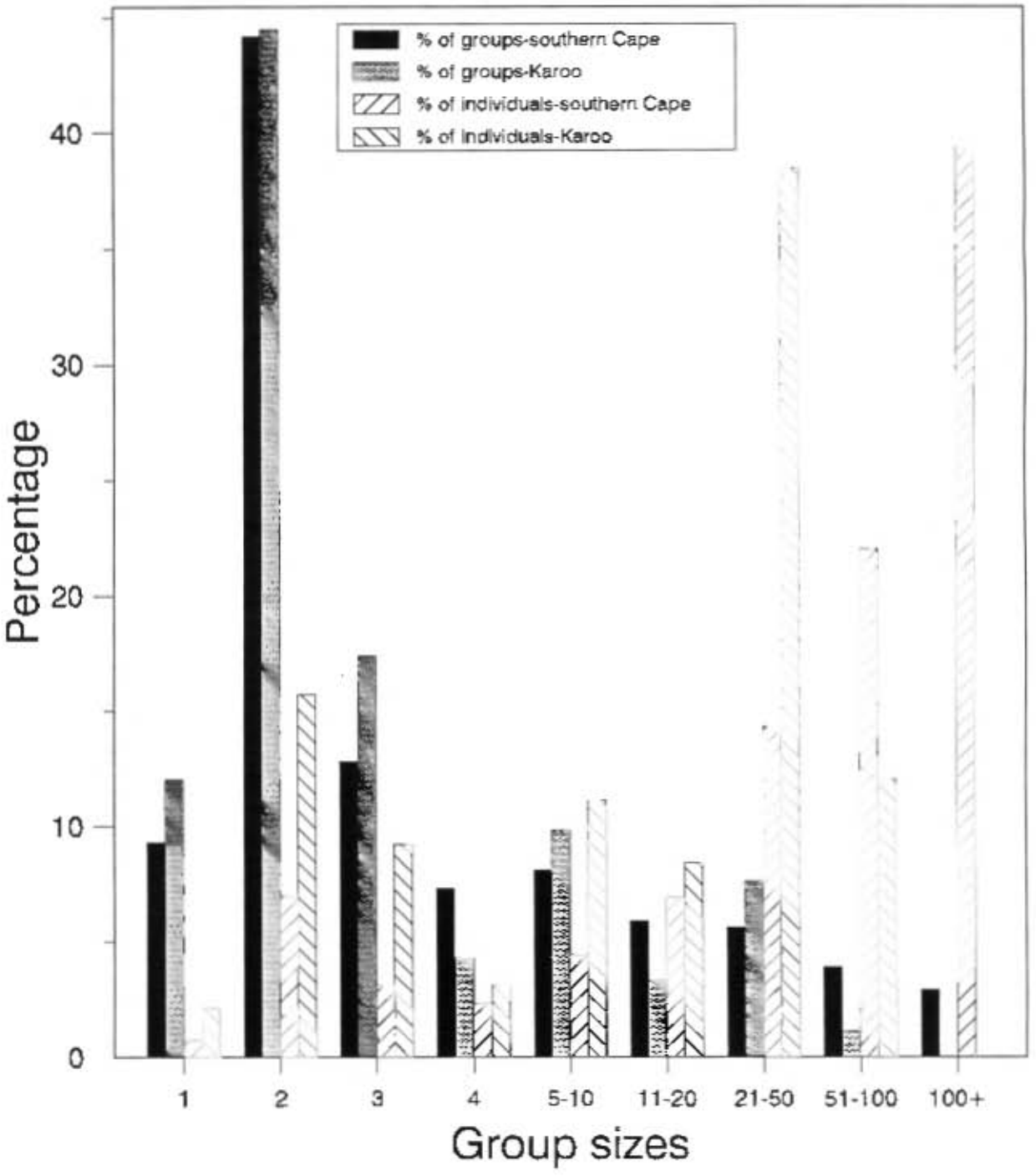

Figure 5.1 The percentage of groups and of individuals of Blue Cranes found in different group size classes in the southern Cape and Karoo.

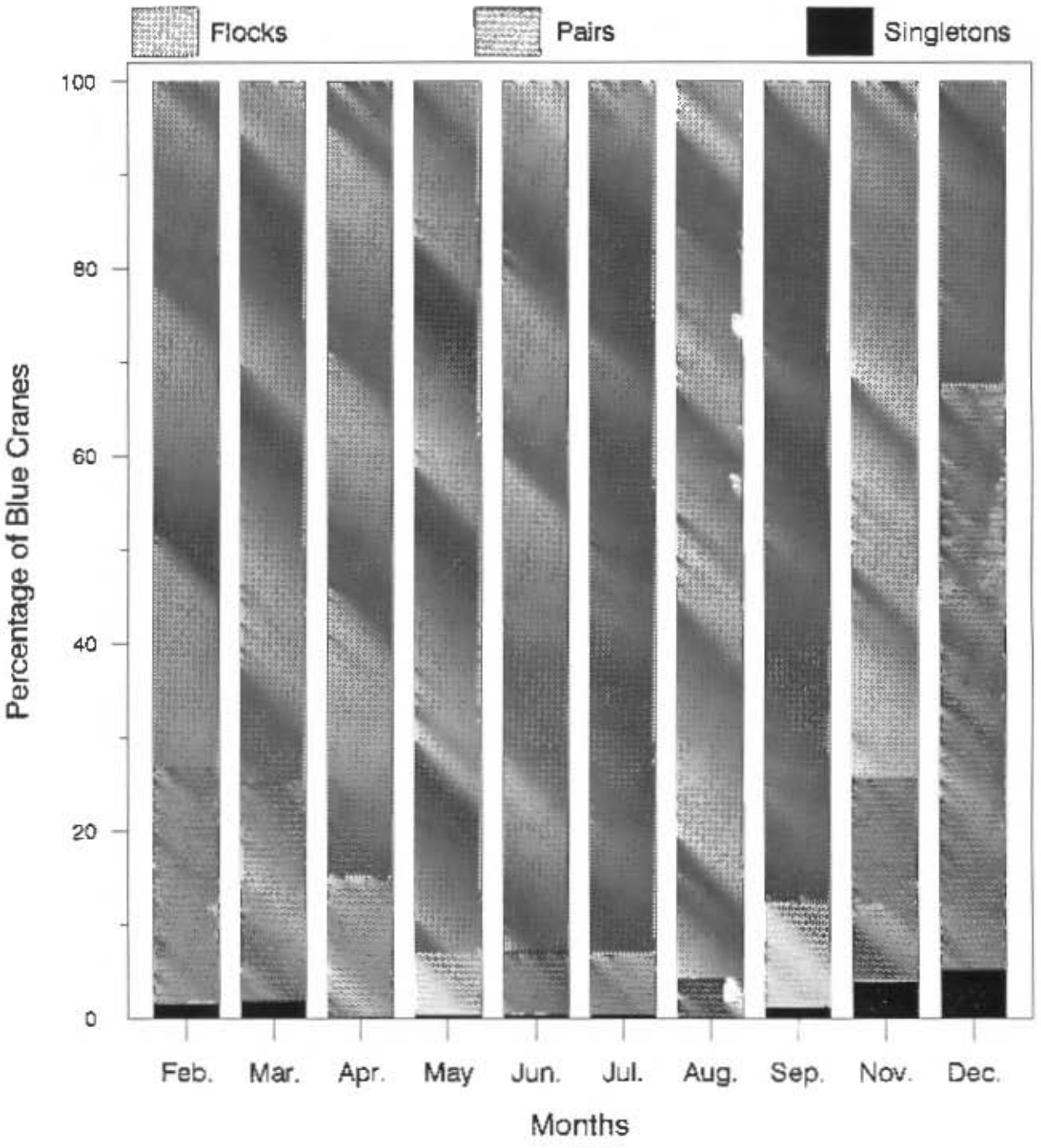

Figure 5.2 The proportion of Blue Cranes found in flocks, in pairs and as singletons in the southern Cape during ten months of the year for which data were available.

Table 5.4 The number of Blue Crane adults seen in pairs and in flocks during road counts in the southern Cape by months.

Month	No. kms	Cranes in pairs/100 km*	Cranes in flocks/100 km
January	-	-	-
February	583	10,3	31,9
March	1157	8,1	27,1
April	588	9,9	56,0
May	605	6,3	83,3
June	1089	6,4	94,5
July	1723	6,2	97,9
August	591	7,5	176,3
September	483	6,6	55,7
October	-	-	-
November	1172	8,5	31,1
December	593	13,8	4,7

* - summer (Nov.-Mar.)/winter (May-Aug.) difference not significant ($U=13$, $P>0,05$, Mann-Whitney U-test)

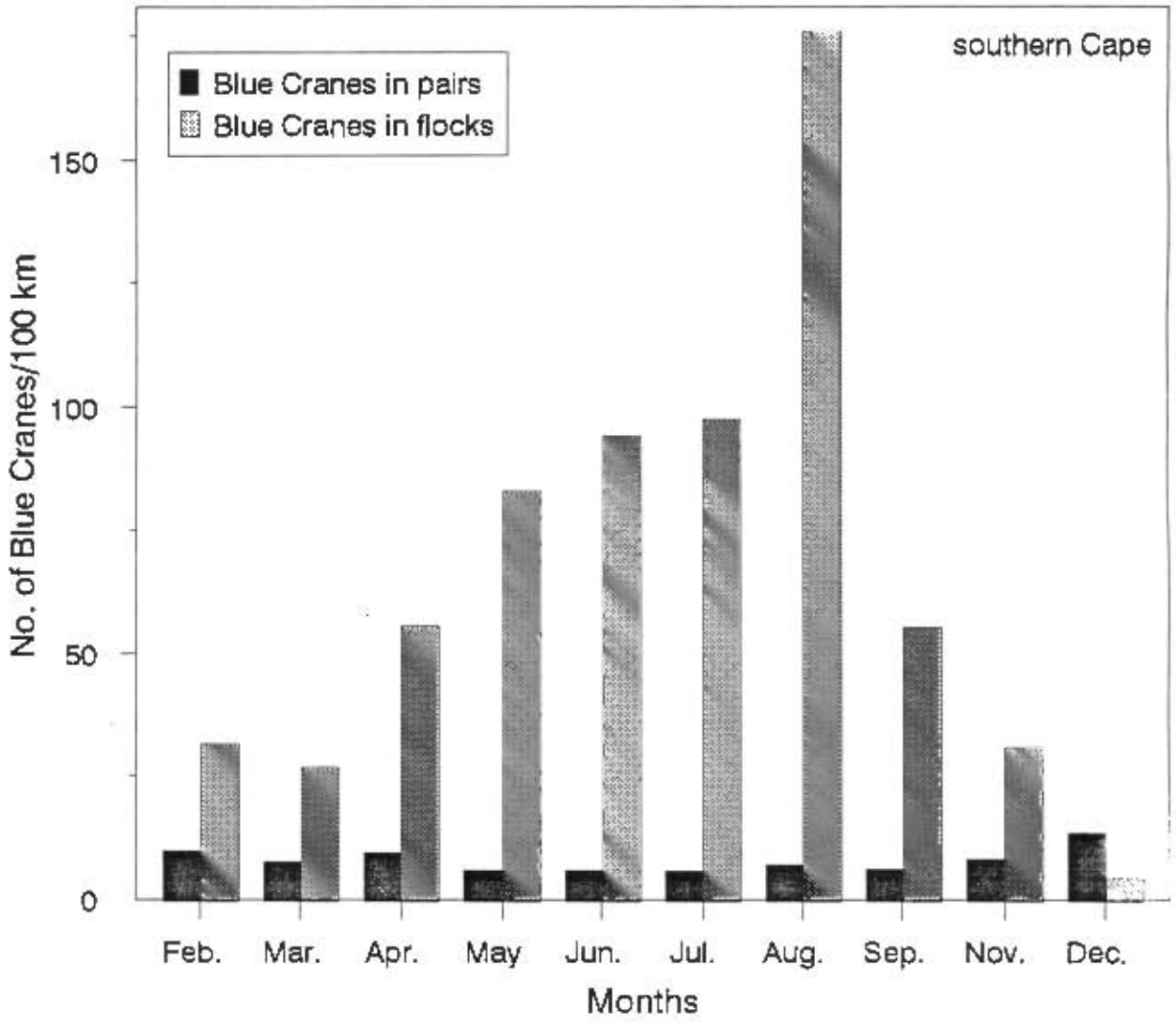

Figure 5.3 The number of Blue Cranes recorded per 100 km of road counts in the southern Cape during ten months of the year for which data were available, presented separately for cranes seen in flocks and in pairs.

Table 5.4 The number of Blue Crane adults seen in pairs and in flocks during road counts in the southern Cape by months.

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October	-	-	-
November	1172	8,5	31,1
December	593	13,8	4,7

* - summer (Nov.-Mar.)/winter (May-Aug.) difference not significant ($U=13$, $P>0,05$, Mann-Whitney U-test)

to the summer emigration of many birds (Chapters 3 and 4) found there in flocks during the winter, rather than due to the increase in the actual number of cranes in pairs (Table 5.4, Figure 5.3). The mean number of adult Blue Cranes recorded in pairs per 100 km of road counts only increased from 6,4 (258 cranes/4008 km) in the winter to 9,6 (336 cranes/3505 km) in the summer. This difference (0,33 times increase in summer) is not significant and is lower than that suggested by the change in proportion from 6,0% in the winter to 27,8% in the summer (4,6 times increase in summer). The road count data suggest that about 33% of pairs join winter flocks, while the proportion data would suggest that about 78% of pairs join winter flocks. The Karoo road count data suggest a similar bias in the proportion data. The mean number of adult Blue Cranes recorded in pairs per 100 km of road counts only increased from 0,9 (36 cranes/4065 km) in the winter to 1,2 (48 cranes/4002 km) in the summer. This difference (0,25 times increase in summer), which cannot be tested statistically, is lower than that suggested by the change in proportion of adults in isolated pairs from 12,4% in the winter to 46,9% in the summer (3,8 times increase in summer). The road count data suggest that about 25% of pairs join winter flocks in the Karoo, while the proportion data would suggest that about 74% of pairs join winter flocks.

A feature of particular interest is the proportion of breeding pairs relative to the total population of Blue Cranes. The above data suggest that during the summer breeding period about 28% of adults in the southern Cape and 47% of adults in the Karoo were found in pairs; this difference was significant ($\chi^2=30,3$, $P<0,001$, d.f.$=1$).

Breeding

Egg-laying dates

Eggs are laid in summer (August-April) throughout the range of the species, with only slight variation between regions (Table 5.5). The peak egg-laying period in the southwestern Cape and in the grassland biome is between October and December. Examining the data from these three months in the two regions suggests that egg-laying is significantly earlier in the southwestern Cape, i.e. there is a significantly higher proportion of records from October in this area. Egg-laying in the Karoo appears to occur evenly throughout the period September-February but data from this biome are few.

Nest sites

Most nests in the grassland biome (97%, 67/69) were in natural grassland and only two were in agricultural fields and cultivated pastures (Table 5.6). This is in marked contrast to the southwestern Cape where the majority (91%, 40/44) were found in

Table 5.5 Egg-laying dates of Blue Cranes in various regions of South Africa (SW Cape = southwestern Cape; O.F.S. = Orange Free State; E Cape = eastern Cape).

Region	Number of records per month Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	n=	Source
SW Cape	-	2	25	25	6	6	1	-	-	65	this study
	-	3	13	14	12	4	-	-	-	46	SAOS NRCs
SW Cape total	-	*5*	*38**	*39*	*18*	*10*	*1*	-	-	*111*	
Karoo	-	3	2	1	5	2	-	-	-	13	this study
	-	1	2	3	1	3	3	-	-	13	SAOS NRCs
Karoo total	-	*4*	*4*	*4*	*6*	*5*	*3*	-	-	*26*	
O.F.S. grassland & Karoo	-	1	9	17	15	9	3	2	1	57	Geldenhuys (1984)
Grassland											
Transvaal	2	9	38	82	36	8	1	1	-	177	Tarboton, Kemp & Kemp (1987)
Natal	-	2	9	20	11	-	-	1	-	43	SAOS NRCs
E Cape		1	4	7	2	-	-	1	-	15	SAOS NRCs
Grassland total	*2*	*12*	*51**	*109*	*49*	*8*	*1*	*3*	-	*235*	
All regions total	2	22	102	169	88	32	8	5	1	429	

* - significantly higher proportion of Oct. records in SW Cape than in grassland ($\chi^2=7,5$, $P<0,05$, d.f.=2)

Table 5.6 Details of Blue Crane nest sites in various regions of South Africa (Nat. veg. - Natural vegetation, Agric. land - Agricultural fields or cultivated pastures).

Region	Habitat		Close to wetland		Nest structure			
	Nat. veg.	Agric. land	Yes	No	Stones	Veg.	Faeces	n=
Grassland	67*	2*	35*	29*	8	22	3	82
Karoo	3	0	1	2	1	1	1	10
SW Cape								
SAOS NRCs	*4*	*8*	*5*	*10*	*3*	*4*	*1*	*19*
this study	*0*	*32*	*5*	*27*	*8*	*15*	*8*	*32*
SW Cape total	4*	40*	10*	37*	11	19	9	51
Total	**74**	**42**	**46**	**68**	**20**	**42**	**13**	

* - significant difference between grassland and SW Cape (habitat-χ^2=81,5, close to wetland-χ^2=11,4, P<0,001 and d.f.=1 for both)

agricultural fields and cultivated pastures. In the latter area 15 nests were in harvested cereal fields, three were in recently ploughed fields and 22 were in cultivated pastures. Most grassland biome nests were situated close to wetlands (55%, 35/64), either in marshes, close to watercourses, or adjacent to open water dams or pans. By contrast, the majority of southwestern Cape nests (79%, 37/47) were situated distant from wetlands. The most commonly recorded nest material was vegetation (dry seeds, twigs, grasses, sedges, *Typha*, *Phragmites*, maize and cereal stalks, roots), followed by small stones (arranged in a pad under the eggs) and pieces of dry mammal (usually sheep and cattle) faeces. All these three major categories of nest material were found in nests in all three regions.

Table 5.7 present details of the nest structure materials found in 19 southwestern Cape nests with eggs which were examined in detail. Only two nest sites had no material. Five types of material were found in the remaining nests: small stones, livestock faeces, twigs, cereal stalks and seeds (in descending order of number of nests with material). The total number of nest material items in nests with material ranged between six and 400 (mean - 115,2, S.D.=95,1, n=17).

Clutch sizes

The modal clutch size is two eggs (88% of records, n=129, Table 5.8) with the remainder (12%) containing a single egg. Only two of the 15 observed single egg clutches in Table 5.8 were confirmed by repeat visits (one during this study). The apparently higher proportion of nests with one egg in the southwestern Cape (14,9%) compared with the grassland biome (8,3%) is not statistically significant.

Brood sizes

All broods contained one or two young (Table 5.9) except for one pair seen with three fledged juveniles in the southwestern Cape during this study (on 8 March 1992 at 34° 14' S, 20° 11' E). This unusual record has not been included in Table 5.9 or in the analysis presented below. The mean unfledged brood size (1,6, n=125) was significantly larger than the mean fledged brood size (1,3, n=149; v^2=30,78, P<0,001, d.f=1). Mean unfledged and mean fledged brood sizes did not differ significantly between the grassland, Karoo and southwestern Cape regions (χ^2=0,89, P>0,05, d.f.=2, χ^2=3,28, P>0,05, d.f.=2, respectively).

Data from the southwestern Cape of young seen with their parents in flocks (Table 5.9) were not included in any of these analyses, although mean fledged brood sizes did not differ significantly between young seen with their parents in flocks and young seen with isolated pairs (1,25, n=152 *vs* 1,31, n=101 respectively; χ^2=0,75, P>0,05, d.f.=1).

Table 5.7 Details of the nest structure of 19 Blue Crane nests in agricultural fields and cultivated pastures of the southwestern Cape.

Nest no.	No. small stones	No. pieces livestock faeces	No. short thick twigs	No. dry cereal stalks	No. dry 'medic' seeds	Total items
1	-	-	75	-	-	75
2	-	-	-	40	-	40
3	-	6	-	2	-	8
4	60	60	20	-	-	140
5	-	20	40	-	-	60
6	-	50	75	-	-	125
7	100	-	60	-	-	160
8	-	-	150	-	-	150
9	-	75	-	-	75	150
10	-	-	10	-	-	10
11	75	-	-	-	50	125
12	100	20	-	-	-	120
13	-	6	-	-	-	6
14	-	30	20	-	-	50
15	250	-	150	-	-	400
16	100	-	10	20	-	130
17	-	-	-	-	-	0
18	-	-	-	-	-	0
19	200	-	10	-	-	210
Total nests	**7**	**8**	**11**	**3**	**2**	

Table 5.8 Clutch sizes of Blue Cranes in various regions of South Africa.

Region	1 egg	2 eggs	Total
Grassland			
Transvaal	1	15	16
Natal	2	37	39
O.F.S.	2	4	6
E Cape	1	10	11
Grassland total	**6***	**66**	**72**
Karoo	**2**	**8**	**10**
SW Cape			
SAOS NRCs	1	17	18
this study	6	23	29
SW Cape total	**7***	**40**	**47**
Total	**15**	**114**	**129**

* - not significantly different ($\chi^2 = 0{,}71$, $P > 0{,}05$, d.f. = 1)

Table 5.9 Unfledged and fledged brood sizes of Blue Cranes in various regions of South Africa. NRCs - data from SAOS nest record cards and from the Cape Nature Conservation data bank, out flocks - brood sizes of breeding pairs seen in family units, i.e. pair plus one or two young, in flocks - brood sizes of pairs accompanied by one or two young and seen in flocks.

Region	Source		1 young	2 young	Total
Unfledged					
Grassland					
Transvaal	NRCs		6	6	12
	this study		4	4	8
Natal	NRCs		5	10	15
O.F.S.	NRCs		0	1	1
E. Cape	NRCs		0	5	5
Grassland total			*15*	*26*	*41*
Karoo	NRCs		5	1	6
	this study		0	10	10
Karoo total			*5*	*11*	*16*
SW Cape	NRCs		13	22	35
	this study		16	17	33
SW Cape total			*29*	*39*	*68*
UNFLEDGED TOTAL			**49**	**76**	**125**
Fledged					
Grassland					
Transvaal	NRCs		2	1	3
	this study		3	2	5
Natal	NRCs		1	1	2
Grassland total			*6*	*4*	*10*
Karoo	this study		20	3	23
Karoo total			*20*	*3*	*23*
SW Cape	NRCs		13	2	15
	this study	out flocks	70	31	101
SW Cape total			*83*	*33*	*116*
FLEDGED TOTAL			**109**	**40**	**149**
TOTAL			*158*	*116*	*274*
(SW Cape	this study	in flocks	114	38	152)

Table 5.10 Fledged brood sizes of Blue Cranes in the southwestern Cape presented separately for each of the four summer breeding seasons between 1989-1993.

Season	1 young	2 young	Total
1989-1990	14	6	20
1990-1991	23	3	26
1991-1992	17	9	26
1992-1993	14	13	27

Table 5.11 The number of Blue Crane pairs with and without fledged young in the post-breeding (late summer) period in the southwestern Cape and Karoo.

Region & date	without Y	with Y	Total
SW Cape			
March 1990	9	10	19
February 1991	16	17	33
March 1992	7	19	26
April 1993	11	19	30
SW Cape total	**43**	**65**	**108**
Karoo			
late summer	23	26	49

Enough data exist from the southwestern Cape to allow some inter-annual comparisons of fledged brood sizes (Table 5.10). A comparison of the four breeding seasons between the summers of 1989-1990 and 1992-1993 revealed a significant difference in fledged brood sizes (χ^2=8,31, P<0,05, d.f.=3), with the summer of 1990-1991 having relatively fewer broods of two young and the summer of 1992-1993 having relatively more broods of two young than would be expected by chance. Expanding this analysis to include brood sizes from pairs with juveniles seen in flocks also shows that significantly more broods of two fledged young were recorded in 1992-1993 (χ^2=11,80, P<0,01, d.f.=3). The two years 1990-1991 and 1992-1993 are the only two years which provide enough data on unfledged brood sizes for statistical testing. More two-chick broods also were recorded in 1992-1993 (57,9%, n=19) than in 1990-1991 (33,3%, n=15), but this difference was not significant (χ^2=1,23, P>0,05, d.f.=1). Road count data also indicate that 1992-1993 was a particularly successful breeding season. A larger number of breeding pairs were recorded per 100 km (6.9) during the early summer of 1992-1993 compared to three previous three summers for which data are available (1988-1989 - 3,7, 1990-1991 -5,3, 1991-1992 - 3,3).

Proportion of pairs with fledged young in the post-breeding period

In the southwestern Cape, the proportion of pairs with fledged young in the post-breeding period (February-April) varied between 51,5% and 73,1% (mean 60,1%, n=108 pairs) during 1989-1993 (Table 5.11). A comparison between each of the four breeding seasons between 1989-1990 and 1992-1993 revealed no significant differences between any of these years in the proportion of pairs with fledged young (χ^2=3,46, P>0,05, d.f.=3). In the Karoo the proportion of pairs with fledged young in the late summer was 53,1% (n=49 pairs, Table 5.11) and did not differ significantly from that found in the southwestern Cape (χ^2=0,44, P>0,05, d.f.=1). These estimates were based on pairs seen alone, as pairs within flocks, especially when unaccompanied by juveniles, could not be identified reliably.

Age ratios

Table 5.12 presents data on the number of adult and juvenile Blue Cranes and the percentage of juveniles recorded in the southwestern Cape and Karoo during various late summer (February-April) and winter (May-August) months between 1988 and 1993. The data from September 1988 have been included in this table but are unreliable and have been excluded from the following analyses, as juvenile Blue Cranes closely resemble adults by September and some juveniles may have been overlooked during that month. Juvenile Blue Cranes were never seen alone and always were accompanied by

Table 5.12 The number of adult and the number and percentage of juvenile Blue Cranes recorded in the southwestern Cape and Karoo between February and September, 1988-1993.

Region & date	Singles			Pairs/Families			Flocks of 3-10			Flocks of >10				
	ads	juvs	% juvs	ads	juvs	% juvs	ads	juvs	% juvs	ads	juvs	% juvs	n=	*Total % juvs*
SW Cape														
Sep. 1988	4	0	0,0%	36	1	2,7%	16	0	0,0%	223	8	3,5%	288	*3,1%*
Jun. 1989	3	0	0,0%	18	3	14,3%	16	1	5,9%	435	34	7,3%	510	*7,5%*
Jul. 1989	1	0	0,0%	32	2	5,9%	16	2	11,1%	348	32	8,4%	433	*8,3%*
Mar. 1990	3	0	0,0%	44	17	27,9%	6	0	0,0%	172	5	2,8%	247	*8,9%*
Jul. 1990	4	0	0,0%	20	6	23,1%	11	1	8,3%	652	48	6,9%	742	*8,8%*
Feb. 1991	4	0	0,0%	66	19	22,4%	11	0	0,0%	175	1	0,6%	276	*7,3%*
May 1991	2	0	0,0%	38	7	15,6%	38	8	17,4%	400	40	9,1%	533	*10,3%*
Jul. 1991	3	0	0,0%	40	5	11,1%	26	2	7,1%	485	42	8,0%	603	*8,1%*
Mar. 1992	5	0	0,0%	52	30	36,6%	25	0	0,0%	107	11	9,3%	230	*17,8%*
Jun. 1992	1	0	0,0%	48	5	9,4%	36	7	16,3%	422	71	14,4%	590	*14,1%*
Aug. 1992	0	0	0,0%	42	1	2,3%	27	4	12,9%	981	87	8,2%	1142	*8,1%*
Apr. 1993	0	0	0,0%	52	27	34,2%	49	6	10,9%	240	22	8,4%	396	*13,9%*
Jul. 1993	2	0	0,0%	8	1	11,1%	7	1	12,5%	387	26	6,3%	432	*6,5%*
SW Cape total	**32**	**0**	**0,0%**	**496**	**124**	**20,0%**	**284**	**32**	**10,1%**	**5027**	**427**	**7,8%**	**6422**	**9,1%**
Karoo														
Mar. 1988	2	0	0,0%	22	4	15,4%	4	0	0,0%	30	1	3,2%	63	*7,9%*
Jul. 1988	2	0	0,0%	16	4	20,0%	15	1	6,3%	0	0	0,0%	38	*13,2%*
Mar. 1989	1	0	0,0%	28	14	33,3%	0	0	0,0%	38	1	2,6%	82	*18,3%*
Jul. 1989	1	0	0,0%	20	6	23,1%	20	7	25,9%	41	5	10,9%	100	*18,0%*
Karoo total	**6**	**0**	**0,0%**	**86**	**28**	**24,6%**	**39**	**8**	**17,0%**	**109**	**7**	**6,0%**	**283**	**15,2%**

their parents and/or were in flocks of conspecifics. An examination of the percentage of juveniles recorded in pairs and families compared to the percentage in small (3-10 birds) and large (>10 birds) flocks showed a significantly higher proportion of juveniles in pairs and families in both the southwestern Cape (χ^2=102,1, P<0,001, d.f.=1) and the Karoo (χ^2=10,92, P<0,001, d.f.=1). The percentage of juveniles recorded in the late summer (February-April) was significantly higher compared with the winter (May-August) in the southwestern Cape (late summer - 12,0%, winter - 8,8%; χ^2=11,36, P<0,001, d.f.=1) but not in the Karoo (late summer - 13,8%, winter - 16,7%, χ^2=0,25, P>0,05, d.f.=1). Comparing the percentage of juveniles in the southwestern Cape and Karoo showed a significantly higher proportion of juveniles in the Karoo in the winter (χ^2=9,29, P<0,005, d.f.=1) but not in the late summer (χ^2=0,24, P>0,05, d.f.=1).

Comparing the percentage of juveniles between years in the southwestern Cape revealed a significant difference between years, examining both the late summer (χ^2=17,19, P<0,001, d.f.=3; data from the four years 1990-1993) and winter (χ^2=9,62, P<0,05, d.f.=4; data from the five years 1989-1993) data. The percentage of juveniles was smaller in the late summer of 1991 and higher in the late summer of 1992 , and was smaller in the winter of 1993 and again higher in the winter of 1992 . There was no significant difference in the Karoo between the percentage of juveniles in the late summer (χ^2=2,42, P>0,05, d.f.=1) and the winter (χ^2=0,17, P>0,05, d.f.=1), comparing the years 1988 and 1989.

A more direct method of measuring inter-annual differences in the number of juveniles in the southwestern Cape is to examine the number recorded during road counts (Table 5.13). The number of juveniles counted per 100 km in the late summer was highest in 1993 (10,4), followed by 1992 (7,2), with lower numbers in 1990 and 1991 (3,8 and 3,1 respectively; no data for 1989). The number of juveniles counted per 100 km in the winter was highest in 1992 (16,3; no data for 1993), with lower numbers in 1989, 1990, and 1991 (8,1, 9,8 and 9,7 respectively).

5.5) *Discussion*

Group sizes

Three previous studies have examined group sizes in Blue Cranes (Geldenhuys 1984, Filmer & Holtshausen 1992, Vernon *et al.* 1992). All three make some attempt to distinguish between 'groups' (singletons and any aggregation of cranes) and 'flocks' (aggregations other than single birds, pairs and families). A flaw in these studies is that groups of three, four and even five cranes were assumed to be families but this was not confirmed by distinguishing juvenile cranes on plumage characters. Blue Crane pairs with three young have never been recorded prior to the single instance reported here

Table 5.13 The number of juvenile Blue Cranes recorded per 100 km in the southwestern Cape between February and September , 1988-1993.

Date	Juveniles/ 100 km	Late summer total	Winter total
1988			
September	2,0	no data	2,0
1989			
June	8,4		
July	7,8	no data	8,1
1990			
March	3,8	3,8	9,8
July	9,8		
1991			
February	3,1	3,1	9,7
May	10,4		
July	8,9		
1992			
March	7,2	7,2	16,1
June	16,0		
August	16,2		
1993			
April	10,4	10,4	no data

from the southwestern Cape. The present study also found that flocks of three to five adult cranes were not unusual. Geldenhuys (1984) found no significant difference in flock sizes (data on group sizes are not mentioned) between seasons in the Orange Free State. Vernon *et al.* (1992) suggest that group sizes (data on flock sizes are not mentioned) were larger in the non-breeding season (winter) in the eastern Cape Karoo and grasslands. Filmer & Holtshausen (1992) suggest that both flock and group sizes were larger in winter (data from throughout South Africa). The latter two studies, however, do not provide statistical confirmation of their results.

Geldenhuys (1984) and Vernon *et al.* (1992) found that the proportion of the population found in isolated pairs or 'families' was higher in the summer. The finding by Geldenhuys (1984) that the proportion of the population consisting of isolated pairs increased from 6% in the winter to 28% in the summer, but that there was no significant difference in flock size between the two periods, suggests that a large proportion of the Orange Free State Blue Crane population comprised non-breeders. This is similar to the situation found in the southwestern Cape and Karoo, although flock sizes were found to be significantly smaller in the former region in the summer during this study. Vernon *et al.* (1992) suggest that at least 75% of Blue Crane breeding pairs join winter flocks but this estimate could be grossly inflated as it is based on an examination of the relative proportion of pairs compared with birds in flocks and therefore is subject to the same bias from migratory movements identified during this study.

Group sizes in different habitat types also have been presented but without any statistical analysis (Filmer & Holtshausen 1992). The largest reported flock size known to the author is of 800-1000 birds seen near Graaf-Reinet in the Karoo on 6 August 1983 (Els & Els 1983).

Many of the singletons encountered during the summer (breeding) period during this study in the southwestern Cape and Karoo probably represented single members of mated pairs the partner of which was incubating and out of view. The increase in the proportion of singletons recorded during the summer supports this view.

Appendix 1.1 in Chapter 1 presents details of the proportion of non-breeders in ten additional species of cranes. The high proportion of non-breeders found during this study in the Blue Crane is not unusual when compared with the data from these other species.

Breeding

Egg-laying dates

The finding that egg-laying occurs in the summer, mainly during October-December, throughout the South African range of the Blue Crane is not novel (Geldenhuys 1984, Siegfried 1985, Tarboton, Kemp & Kemp 1987, Vernon *et al.*

1992). This study, however, is the first to identify that egg-laying is significantly, if only slightly, earlier in the southwestern Cape. Winterbottom (1963) identified an earlier breeding peak in the winter rainfall southwestern Cape, compared with the rest of the sub-continent, when examining the breeding seasons of the avifauna of southern Africa as a whole.

Nest sites

Walkinshaw (1963) provides the only previous detailed study of Blue Crane nest sites. The present study reveals that there is a clear dichotomy in the choice of nest sites by the species between the grassland biome and the southwestern Cape. In the former area Blue Cranes typically nest in natural vegetation close to water, while in the latter region they usually nest in agricultural fields or cultivated pastures away from wetlands. Walkinshaw (1963) was the first to identify the frequent use of small stones as a nest platform. The present study shows that this habit is ubiquitous throughout the South African range of the species but that vegetation is the most frequently recorded nest material and that the total absence of nest lining material is rare. The closely related Demoiselle Crane also lines its nests with small stones (Schoff 1991); a habit unknown in the other 13 wetland-nesting crane species. Walkinshaw (1963) found that nests situated in wetland habitats frequently were constructed of copious wetland vegetation, while eggs laid in dryland positions usually were placed on a platform of stones.

Clutch sizes

The Blue Crane clutch size data from this study confirm existing knowledge, i.e. a modal clutch of two eggs, occasionally one and very rarely three (Walkinshaw 1973, Maclean 1993, Brown 1992a, Vernon *et al.* 1992). Walkinshaw (1963) found tha in Natal hatching success was high: 89% of eggs hatched and in 93% of nests at least one egg hatched. Clutch sizes in cranes are conservative. All the *Grus* and *Anthropoides* cranes typically lay two eggs (Johnsgard 1983). The crowned *Balearica* spp. and Wattled *Bugeranus carunculatus* Cranes are unusual; the former regularly laying three eggs (Walkinshaw 1973, Tarboton 1992a) and the latter frequently having single egg clutches (Tarboton, Barnes & Johnson 1987). Appendix 1.2 in Chapter 1 presents details of clutch sizes in all 15 species of cranes.

As the incubation period in the Blue Crane is about 30 days and the second egg is laid two or three days after the first (Walkinshaw 1963), it might be expected that about 7-10% of nests visited only once would have incomplete clutches. The majority of nests visited during this study and reported in the SAOS nest record cards were visited only once. This suggests that many, if not most, of the single egg clutches reported in Table 5.8 represent incomplete clutches.

Brood sizes

Filmer & Holtshausen (1992), based on data collected throughout South Africa, report that 50% of unfledged Blue Crane broods consisted of two young (n=92) and Brown (1992a) found that 58% of broods (information on unfledged and fledged broods not distinguished) at Etosha Pan, Namibia, consisted of two young (n=12). During the present study 60% of unfledged broods consisted of two young and 30% of fledged broods consisted of two young. Although these data suggest an appreciable intra-brood loss of a single young in two young broods between hatching and fledging, it is obvious that both young from the typical two egg clutch frequently survive. This is contrary to many statements that cranes rarely rear two young per breeding attempt (e.g. Johnsgard 1983). Appendix 1.3 in Chapter 1 presents details of unfledged and fledged brood sizes in eight additional species of cranes and discusses the rearing of two young in cranes in more detail. The brood of three fledged young recorded in the southwestern Cape during this study is the only one reported for the Blue Crane and may have involved an 'adopted' juvenile, as reported once for the Redcrowned Crane *G. japonensis* (Masatomi 1972).

Proportion of pairs with fledged young in the post-breeding period

The data on the proportion of Blue Crane pairs with fledged young in the post-breeding period, which was based on observations of pairs which were not in flocks, could be biased if pairs with fledged young tend to avoid flocks. The alleged avoidance of flocks by pairs with juveniles has been claimed for the Eurasian *G. grus* and Sandhill *G. canadensis* Cranes (Miller & Hatfield 1974, Tacha & Vohs 1984, Alonso, Veiga & Alonso 1987, Bishop 1988). Appendix 1.7 in Chapter 1 presents details of the proportion of pairs with fledged young in the post-breeding period for four additional crane species.

Age ratios

The proportion of juvenile (post-fledging) birds in crane populations, as assessed during the post-breeding period, has been used widely to estimate the breeding productivity of many species (e.g. Miller & Hatfield 1974). These data also have been used as a basis for assessing the conservation health of cranes. For example, Archibald *et al.* (1981) state that healthy populations of cranes should have about 10-15% juveniles in the post-breeding period. The collection and interpretation of age ratio data for cranes, however, must be done with care as the results can be influenced by several confounding variables. For example, the proportion of juveniles may change, not as a result of changes in breeding success, but due to a change in the number of adults,

especially non-breeding birds, e.g. through migration into or out of the study region (e.g. Lovvorn & Kirkpatrick 1982b). Caughley (1974) is particularly critical of the interpretation of age ratio data in biological investigations. He shows that age ratio data alone are totally unreliable in assessing population health. He points out that such data must be interpreted in conjunction with information on other aspects of population demography (proof of stability or rate and direction of population increase or decrease, and information on survival and fecundity). However, as age ratios usually are used (incorrectly) as an indirect estimate of these demographic factors, direct information on them renders age ratio data redundant, at least as an indicator of population health.

The finding that the percentage of juveniles in the southwestern Cape was significantly higher in the late summer compared with the winter could reflect mortality of juveniles between the two periods. Similarly, the significantly higher percentage of juveniles in the Karoo in the winter, compared with the southwestern Cape, could reflect higher breeding success in the former region. These data, however, are biased by the large influx of Blue Cranes into the southwestern Cape during the winter (Chapter 4). It could be expected that these migrants might have had a lower proportion of juveniles if successful breeding adults from elsewhere were less likely to migrate into the region than unsuccessful and non-breeding adults.

The finding that lower proportions of juveniles occurred in large flocks, compared with data from isolated pairs and family parties, identifies the need to sample all groups when assessing age ratios. The lower proportion of juveniles counted in flocks compared with isolated pairs has been interpretated as evidence that pairs with fledged young tend to avoid flocks (e.g. Miller & Hatfield 1974, Tacha & Vohs 1984, Alonso, Veiga & Alonso 1987, Bishop 1988). It, however, is more likely to be due to the presence of non-breeders in flocks, an alternative explanation apparently not previously suggested. The proportion of juveniles found in a sample of 42 poisoned Blue Cranes from the southwestern Cape in August 1991 (Chapter 7) was 7,1% (3/42), which accords with the percentages of juveniles found during this study. Appendices 1.9 and 1.10 in Chapter 1 present details of the percentages of juveniles in 12 additional species of cranes. The information revealed by the present study suggests that the percentage of juveniles in Blue Crane populations is similar to that found in most other species.

Inter-annual breeding success in the southwestern Cape 1988-1993

Table 5.14 presents the annual data (1988-1993) from the southwestern Cape on various aspects of breeding that might be expected to be associated with breeding productivity. In all entries in this table larger values could be expected to reflect higher breeding effort and success. The data in the table are incomplete, especially for the 1988-1989 breeding season. These data do not unequivocally identify years of higher

Table 5.14 Summary of information possibly associated with breeding effort and success in Blue Cranes in the southwestern Cape during the five breeding seasons between 1988 and 1993. y = young, juvs = juveniles, nd = no or few data, *- = significantly lower than the other values in that column, *+ = significantly higher than the other values in that column.

Breeding season	Pairs/ 100 km spring	Mean unfledged brood size	Mean fledged brood size	% pairs with fledged y late summer	% juvs late summer	% juvs winter	Juvs/ 100 km late summer	Juvs/ 100 km winter
1988-89	3,7	nd	nd	nd	nd	7,8	nd	8,1
1989-90	nd	nd	1,3	52,6	8,9	7,4	3,8	9,8
1990-91	5,3	1,3	1,1*-	51,5	7,3*-	9,2	3,1	9,7
1991-92	3,3	nd	1,4	73,1	17,8*+	10,1*+	7,2	16,3
1992-93	6,9	1,6	1,5*+	63,3	13,9	6,5*-	10,4	nd

and lower breeding success, but they suggest that the breeding seasons of 1991-1992 and 1992-1993 had higher breeding productivity than the seasons of 1989-1990, 1990-1991 and, perhaps, 1988-1989. The significantly lower proportion of juveniles counted in the winter of 1993 is surprising considering the evidence from other sources suggesting that the previous breeding season had high breeding success. As discussed above, however, this value could be biased by the influx of Blue Cranes from elsewhere into this region during the winter.

Rainfall patterns in this region during the study period do not clarify this issue (Figure 5.4). Rainfall immediately preceding the 1988-1989 and 1990-1991 breeding seasons was poor, that preceding the 1989-1990 and 1992-1993 was above normal, and that preceding the 1991-1992 season was mixed, being above average in May-July and October, and low in August-September and November.

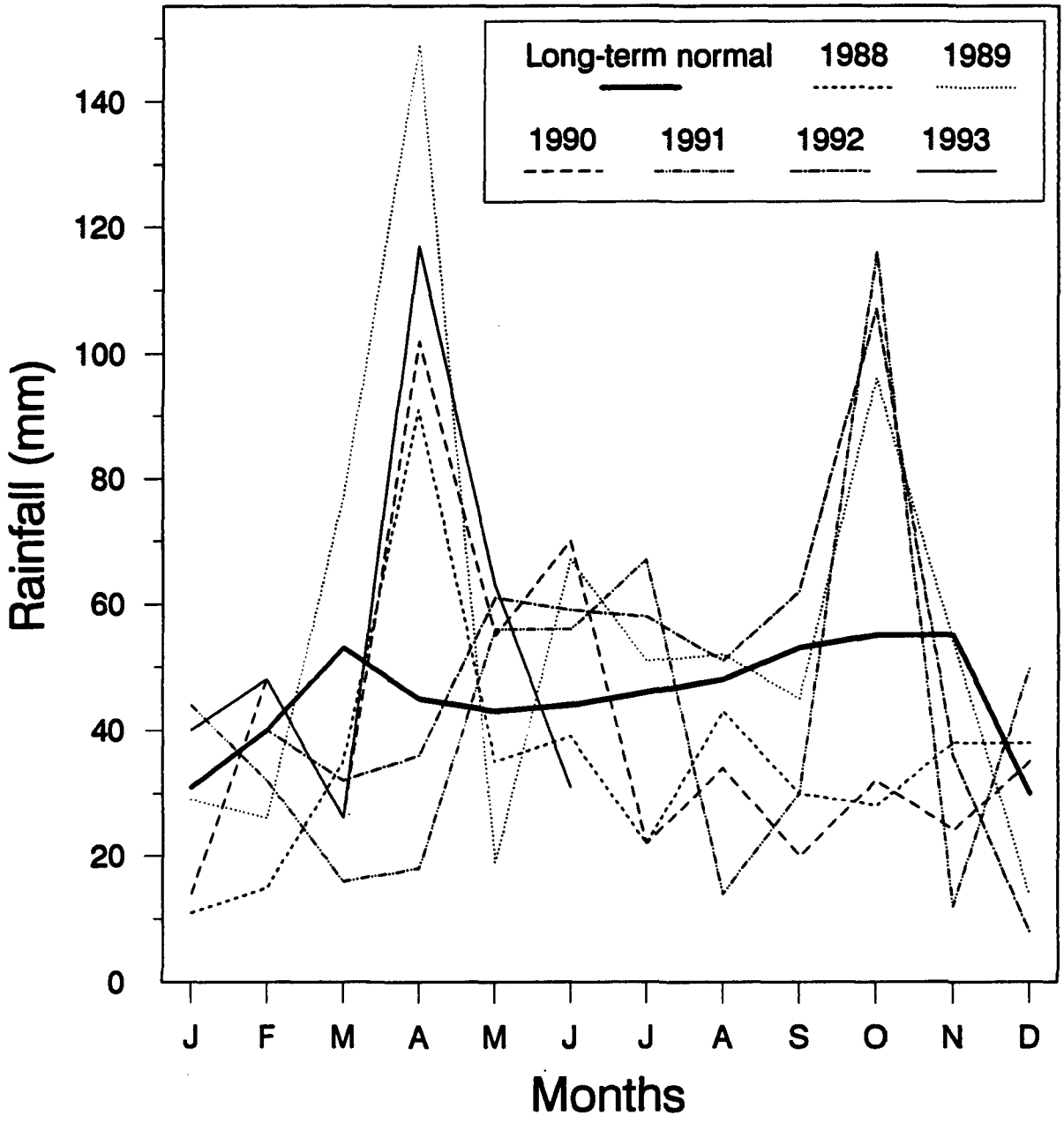

Figure 5.3 The number of Blue Cranes recorded per 100 km of road counts in the southern Cape during ten months of the year for which data were available, presented separately for cranes seen in flocks and in pairs.

CHAPTER 6

HABITAT SELECTION BY BLUE CRANES *ANTHROPOIDES PARADISEUS* IN THE SOUTHWESTERN CAPE AND THE KAROO

CHAPTER 6

HABITAT SELECTION BY BLUE CRANES *ANTHROPOIDES PARADISEUS* IN THE SOUTHWESTERN CAPE AND THE KAROO

SUMMARY

Blue Cranes Anthropoides paradiseus *in the southwestern Cape inhabited cultivated pastures and agricultural fields and in the Karoo they inhabited natural vegetation. In the southwestern Cape, harvested cereal fields were highly favoured during November to May when they were available. Fields with growing crops were selected in June, when the crop plants were small, but were avoided between July and September, when the crops were taller. Cultivated pastures were selected for during July to September and were used less frequently during November to June. Ploughed fields were used in proportion to their availability. Natural vegetation and miscellaneous habitats were avoided throughout the year. Patterns of habitat selection by foraging cranes were the same as for cranes involved in other activities. Blue Cranes fed at small stock feedlots in the southwestern Cape, especially during the winter. Habitat availability in the southern Cape and Swartland appeared similar and did not explain the wide difference in Blue Crane abundance between the two regions. Blue Cranes used open water roosts in the southwestern Cape and frequently flew to these after dark.*

6.1) *Introduction*

Most cranes are associated with wetlands when breeding, but all species (except the Siberian Crane *Grus leucogeranus*, Archibald *et al.* 1981) regularly forage in dryland habitats, especially out of the breeding season (Johnsgard 1983). The Blue *Anthropoides paradiseus* and Demoiselle *A. virgo* Cranes are entirely independent of wetland habitats throughout the year (Johnsgard 1983). Cranes are attracted to crop fields where they feed mainly on fallen grain (e.g. Sugden *et al.* 1988). Their presence in agricultural areas can bring them into conflict with man (e.g. Walkinshaw 1981a).

The natural habitat of the Blue Crane in South Africa is grassland and a combination of grassland and dwarf shrubland (grassy Karoo) (Maclean 1993, Chapter 2). Like other cranes, the Blue Crane has adapted to feeding in agricultural fields where it frequently is persecuted as a threat to crops (e.g. Geldenhuys 1984, Vernon *et al.* 1992, Chapter 8). The present study describes habitat availability and selectivity of the species in the southwestern Cape and the Karoo regions of South Africa.

All cranes, including Blue Cranes (Tarboton, Kemp & Kemp 1987), show a strong preference for roosting overnight in shallow waterbodies (e.g. Lovvorn & Kirkpatrick 1981). This habit has a strong influence on other aspects of the spatial dispersion of

cranes within their habitat (Sugden *et al.* 1988) and has obvious significance for potential crop damage, conservation and management (e.g. Archibald *et al.* 1981). Details of the roosting habits of Blue Cranes have not been reported.

Some preliminary results of this study were presented in Allan (1992).

6.2) *Aims*

The aims of this study were to examine habitat availability and use by Blue Cranes in the southwestern Cape and Karoo, including the use of open water overnight roosts.

6.3) *Study areas and methods*

Most of the observations on Blue Cranes used in this study were collected during road counts made in the southwestern Cape and Karoo during 1988-1993. Details of these counts are given in Chapter 3. The methods employed during all of the counts were similar. The vehicle was stopped briefly when cranes were seen and details of the time of day, locality, group size, activity, and habitat were recorded. During the stop all cranes visible in the area were considered as part of the same group even if they were relatively widely dispersed. In assessing the use of habitat by cranes, chicks, i.e. less than full size and incapable of proper flight, were disregarded. Observations were stopped while travelling through built-up areas.

Habitat availability, in addition to habitat use, was measured during road counts to assess habitat selectivity by Blue Cranes. In the three Karoo biogeographical regions where Blue Cranes were recorded regularly (Central Upper, Great and Steytlerville Karoo regions, Chapter 3), which comprise mainly natural vegetation, the total number of kilometres along the road count route within man-altered habitats was recorded and compared with the number of kilometres within natural vegetation. During the road counts in the two southwestern Cape regions where Blue Cranes occur, i.e. the southern Cape coastal plain between Bot River and Mossel Bay and the Swartland (Chapter 3), which traverse mainly agricultural areas and where the habitat patches are smaller than in the Karoo, the habitat types on each side of the road were recorded at exactly one kilometre intervals along the two routes during all road counts except for two of the 15 counts made in the southern Cape study area.

Chi-square goodness of fit tests were used to test the selectivity of habitats by Blue Crane groups relative to the availability of the habitats. It was not permissible to compare statistically the availability of each habitat with its selection by individual Blue Cranes, as the flocking habits of the species (Chapter 5) resulted in the non-independence of the information relating to each individual (Alldredge & Ratti 1986). It was permissible, however, to statistically compare the selection of habitats by Blue

Crane groups in relation to their availablity. Therefore the results of the statistical tests presented here refer to habitat selection by groups of Blue Cranes.

Two open-water roost sites used by large numbers of cranes were found in the southern Cape region. They were visited to count the number of cranes present; one was visited three times, once at dusk (19 June 1991) and twice at dawn (22 June 1991, 6 June 1992), and the other once at dusk (1 June 1992). The former site is a *ca* 14 ha man-made dam near Rietpoel (34° 15'S, 19° 45'E) and the latter is a *ca* 20 ha natural endorheic pan near Riversdale (34° 10'S, 21° 11'E).

6.4) *Results*

Habitat availability and use

Karoo

In the Karoo, 1950 km of the road count route passed through natural vegetation and only 100 km (4,9%) was through agricultural fields. Eighty-nine percent of Blue Crane individuals (n=423) and 96% of groups (n=81) were found in natural vegetation and the remainder (48 individuals in three groups) were in agricultural fields (fallow croplands). The number of groups in fields did not differ significantly from the number expected if no habitat selection occurred (χ^2=0,09, P>0,05, d.f.=1) but the number of individuals found in agricultural fields was relatively high.

Southern Cape

In the southern Cape, the available habitats were more diverse and varied seasonally according to crop farming practices. Four broad habitat types were identified: cultivated dryland pastures of grasses, scattered lucerne plants, etc. ('pastures'); agricultural crop fields, mainly cereal crops, e.g. wheat, oats, barley, etc. ('fields'); natural vegetation, i.e. fynbos, renosterveld and strandveld (Moll & Bossi 1983); and a miscellaneous category encompassing alien trees, homesteads, smallholdings, vineyards, orchards, and irrigated crop fields and pastures along rivers. The relative proportions of the study area covered by each habitat type were: pastures - 46,3%, fields - 33,6%, natural vegetation - 11,3% and miscellaneous - 8,8% (Appendix 6.1, Figures 6.1 and 6.2). The fields consisted of three types depending on the stage of the crop farming cycle: harvested fields, fields with growing crops and recently ploughed fields. Recently ploughed fields were most common during April to May, the sowing season, but also were present throughout the rest of the year at lower frequencies (Appendix 6.1, Figures 6.1 and 6.2). Fields with growing crops were present mainly between June and September, in the period immediately following sowing. Harvested fields ('stubble fields') were present mainly from November to March, with some remaining during April and May.

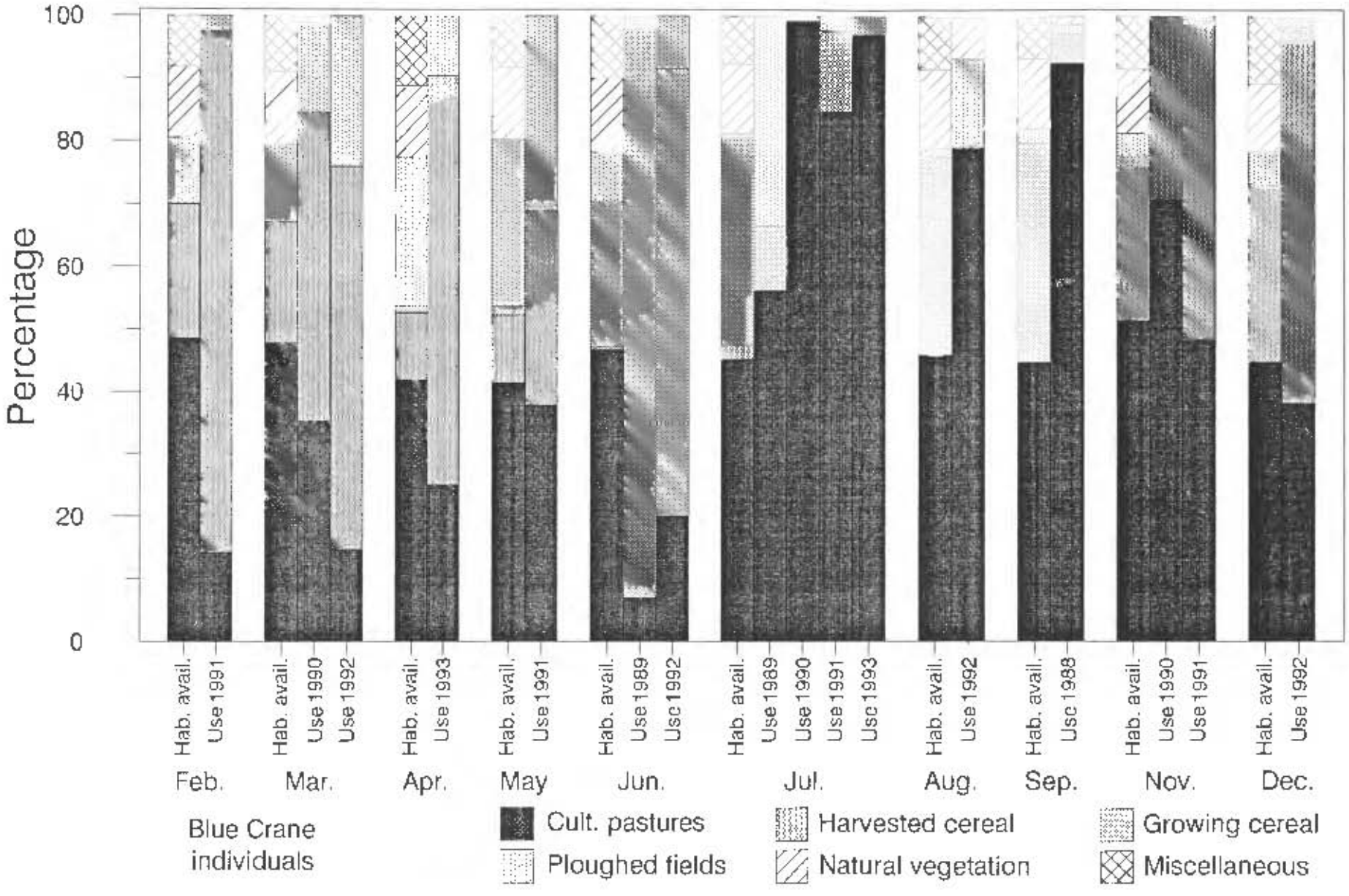

Figure 6.1 Availability and use of six habitats by Blue Crane individuals in the southern Cape, data presented separately for each month.

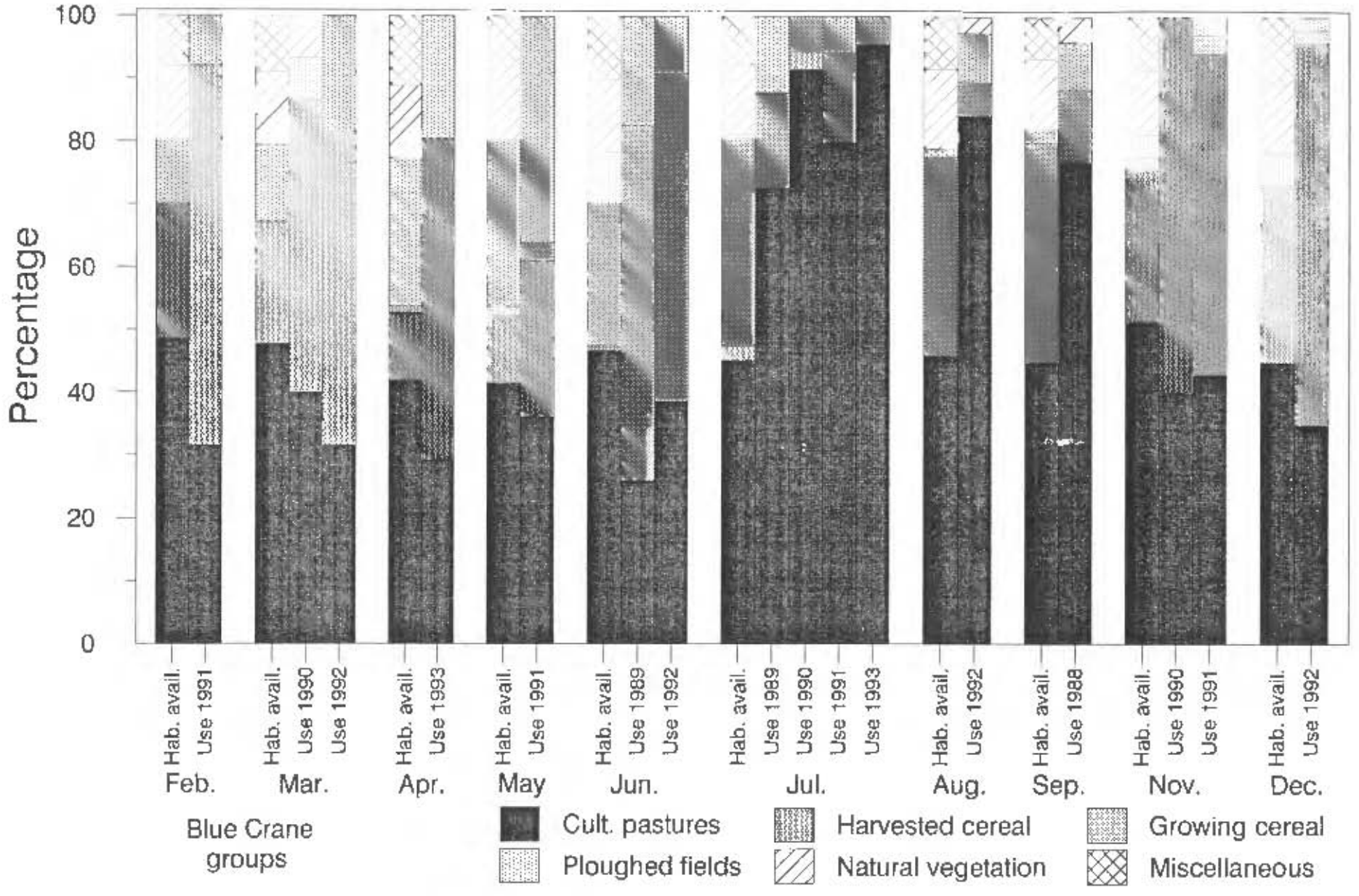

Figure 6.2 Availability and use of six habitats by Blue Crane groups in the southern Cape, data presented separately for each month.

Blue Cranes in the southern Cape were highly selective in their use of these various habitats. Although only the significance of habitat selection by Blue Crane groups could be tested, the patterns of habitat selection by individuals and groups were similar (Appendix 6.1, Figures 6.1 and 6.2).

The areas included in the miscellaneous category were avoided completely (Table 6.1, Figures 6.1, 6.2 and 6.3). Natural vegetation also was avoided and only 86 Blue Cranes in four groups, out of a sample of 7216 Blue Cranes in 574 groups, were found in this habitat. Harvested fields were highly favoured throughout the period November to May when they were available. Fields with growing crops were selected during June, when the crop plants were small, but were avoided from July to September, when the plants were taller. There was no obvious pattern to the use of ploughed fields, which were both available and used throughout the year. When the data from ploughed fields for all months were pooled, this habitat was used in proportion to its availablity. Cultivated pastures also were available and used throughout the year, but were used more than expected during July to September and less than expected between November and June.

These patterns of habitat selection cannot be equated with the selection of foraging areas as the activity of the Blue Cranes was not taken into account and some Blue Cranes fed from feedlots established by farmers for small stock (Merino sheep). Therefore some birds may have been attracted to the habitats for activities other than foraging and also may have been attracted to the food at feedlots rather than in the surrounding habitat. In addition, some Blue Cranes were present at some sites to drink from livestock water troughs and small dams rather than for foraging. In order to investigate the selection of foraging habitats by Blue Crane groups, analysis was restricted to groups which were foraging away from feedlots. This analysis showed that habitat selection by foraging Blue Crane groups as was the same as habitat selection by all groups combined (Table 6.1).

Blue Cranes were observed feeding at feedlots on 51 occasions. Most of these (40) were in pastures, five were in harvested fields, four were in ploughed fields, one was in a field with growing crops, and one was in natural vegetation. Most observations of Blue Cranes at feedlots (42) were made during the winter (May-August), and a relatively high proportion of Blue Cranes were observed at feedlots during this period (26,2%, 1360/5192).

Swartland

The patterns of habitat availability in the Swartland, i.e. pastures - 34,9%, fields - 46,9%, natural vegetation - 1,6% and miscellaneous - 16,5%, were similar to the southern Cape (pastures - 46,3%, fields - 33,6%, natural vegetation - 11,3% and

Table 6.1 Summary of the patterns of selection of six habitat types by Blue Crane groups in the southern Cape. Data presented separately for all groups (All) and for groups recorded actively foraging and away from feedlots (Foraging).

Habitat	Availability		Selection	All $\chi^2=$	All P^*	Foraging $\chi^2=$	Foraging P^*
Cult. past.	all year	Jul.-Sep.	positive	59,21	<0,001	34,37	<0,001
		Nov.-Jun.	negative	10,13	<0,01	5,39	<0,05
Harv. fields	Nov.-May		positive	164,27	<0,001	74,62	<0,001
Growing cereal	Jun.-Sep.	Jun.	positive	26,23	<0,001	8,37	<0,01
		Jul.-Sep.	negative	31,38	<0,001	20,51	<0,001
Plough. fields	all year		neutral	0,11	n.s.	0,13	n.s.
Natural veg.	all year		negative	57,17	<0,001	25,38	<0,001
Misc.	all year		negative	49,52	<0,001	22,51	<0,001

* - d.f. = 1 in all Chi-square goodness of fit tests

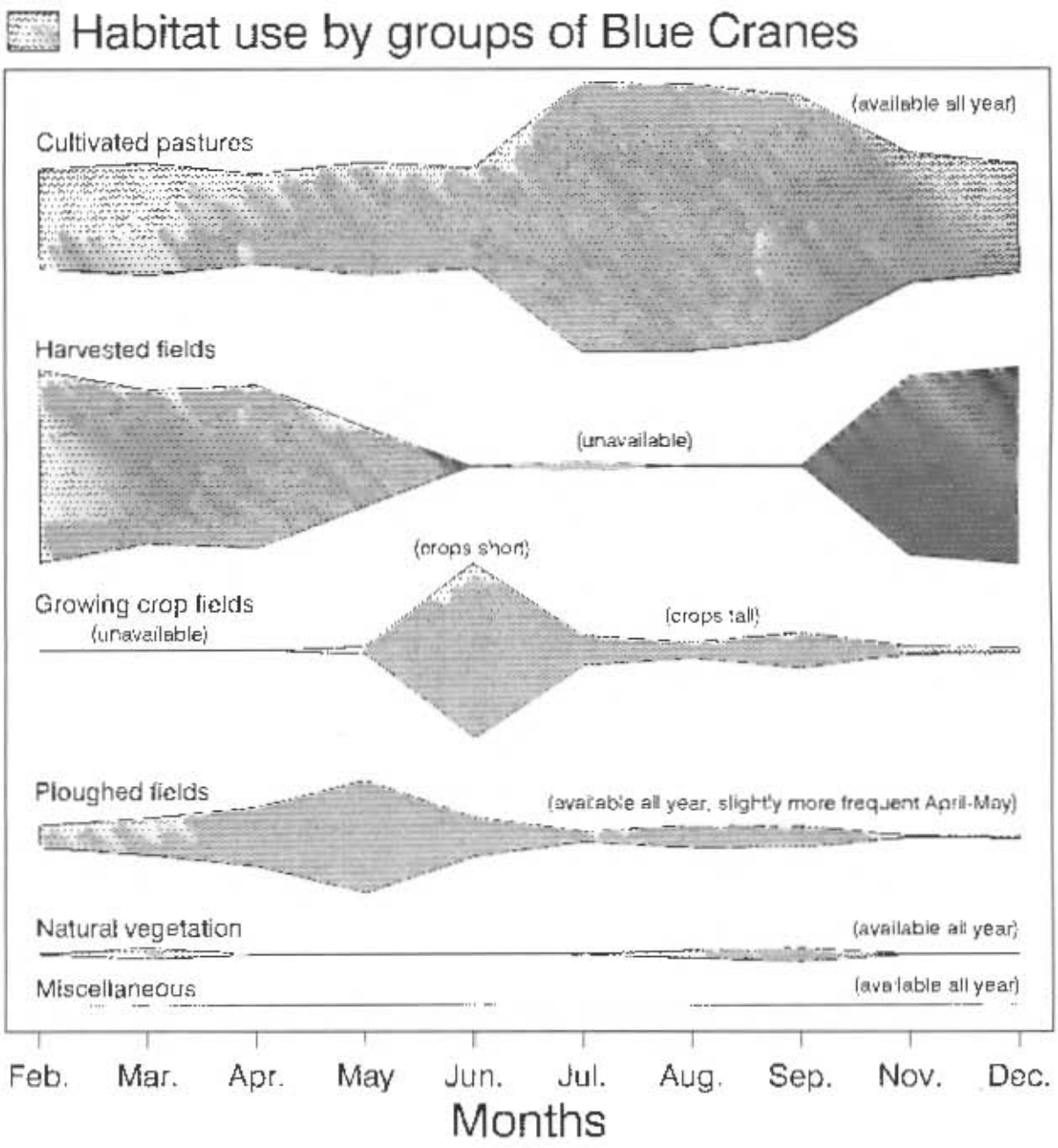

Figure 6.3 Summary of use and availability of six habitats by Blue Cranes in the southern Cape.

miscellaneous - 8,8%), with the former region having more fields and miscellaneous habitats and less pastures and natural vegetation. The types of crops in the two areas also were similar, i.e. largely cereal crops, and the fields consisted of harvested fields, fields with growing crops and ploughed fields, the relative proportions of which depended on season. Too few Blue Cranes were recorded in this region for any meaningful analysis of habitat use, i.e. 74 individuals in 8 groups (10 individuals in three groups in pastures, seven individuals in three groups in fields with growing cereal crops and 57 in two groups in ploughed fields).

Roosts

During the visit to the Rietpoel roost in the late afternoon, 127 Blue Cranes were present in the area surrounding the dam when observations started at 17h30. An additional 13 groups flew in between 17h30 and dusk (18h45), when it became too dark to see inflying birds. The mean group size of these 13 groups was 14,0 (S.D.=12,9, range=2-47). At dusk all birds moved down to the dam and waded into shallow water. Blue Cranes continued arriving at the roost after dark and were revealed by their vocalizations as they approached the roost. Three hundred and nine birds were counted at the roost before it became too dark to see arriving birds. It is likely that a substantial number of birds arrived after dark as a visit to the roost in the early morning three days later revealed 1160 Blue Cranes in the dam at first light (07h00) on a clear day. The birds left the roost followed shortly after this and by about 20 minutes after first light most of the birds had dispersed from the roost. This site was visited again at dawn about a year later and 202 birds were found at the roost. Weather conditions were misty on this occasion and dispersal from the roost was later than on the first dawn visit. The first birds flew off at 07h50 (50 minutes after first light) and the last left at 08h10. The mean group size of birds flying away from the roost was 13,5 (S.D.=12,5, range 1-40).

The Blue Cranes were highly vocal at the roost. They frequently called while standing in the shallow water and in flight. A distinctive high pitched call was noted from some flying individuals: this call was not noted at any other time during this study of the species.

The observations at the roost near Riversdale in the late afternoon were similar to those at the Rietpoel roost. Two hundred and ten birds were counted at the roost before it became too dark to see inflying birds and additional birds were heard flying in after dark.

6.5) *Discussion*

There was a clear difference in habitat selection by Blue Cranes in the Karoo and southern Cape. In the Karoo, although there may have been some selection for the few

agricultural fields, the vast majority of the cranes occurred in natural vegetation. In the southwestern Cape, agricultural fields and pastures were used almost exclusively and natural vegetation was avoided. This avoidance of natural vegetation in the southwestern Cape strongly accords with other evidence (Chapter 2) that the Blue Crane is a relatively recent colonizer in this region, following the establishment of extensive agriculture. Winterbottom (1978) commented that the birds inhabiting the agricultural areas of the fynbos biome are characteristic of grasslands and not the indigenous vegetation of this biome.

Geldenhuys (1984) reported that Blue Cranes in the Orange Free State (grassland and Karoo biomes) favoured areas of natural vegetation and harvested maize fields, where fallen grain was fed on, but that they regularly were found in a wide variety of other agricultural crop fields. Filmer & Holtshausen (1992), reporting on a survey from throughout the South African range of the species, found that 46% of Blue Crane records came from natural vegetation and the remainder were from cultivated pastures and crop fields, especially maize and wheat fields.

Harvested fields probably were the most preferred habitat in the southern Cape because fallen grain is a common food item in these fields. This was not confirmed during this study, however, as neither diet nor food availability were investigated. It is an apparent paradox that the influx of large numbers of Blue Cranes into the southern Cape in the winter (Chapter 4) occurs at the time when the most highly favoured habitat, harvested fields, is scarce.

The apparent selection of pastures between July and September by Blue Cranes in the southern Cape may have been partly due to the scarcity of the other three favoured habitats, i.e. harvested fields, fields with small growing crops and ploughed fields (Appendix 6.1, Figures 6.1 and 6.2), at that time, rather than due to any active selection of pasture habitats. In addition, most feedlots, which mainly were fed from in the winter, were in pastures, partially explaining the highly significant selection for this habitat during this period. However, controlling for this factor by only examining data from birds foraging away from feedlots still resulted in a significant selection for pasture habitats during the winter. The relatively high proportion of birds found at feedlots suggests that they represented an important food supply.

The adaptation by Blue Cranes to intensively agriculturalized habitats parallels the situation reported for many other crane species. For example, Reinecke & Krapu (1986) describe how the Sandhill Crane *G. canadensis* has adapted to exploiting a combination of crop fields and natural and cultivated pastures in an agricultural landscape. They suggest that, in such regions, habitats providing animal protein foods are likely to be the limiting resource, rather than habitats providing vegetable foods. Several other studies report extensive use of man-made habitats by cranes (Lovvorn &

Kirkpatrick 1982a, Alonso, Alonso & Veiga 1984, Krapu *et al.* 1984, Iverson *et al.* 1985, 1987, Sugden *et al.* 1988, Khachar *et al.* 1991, and McIvor & Conover 1992).

The slight differences between the southern Cape and Swartland in the relative abundance of the four major habitat types do not explain the large difference in the abundance of Blue Cranes between the two areas (Chapter 3). This dichotomy in patterns of abundance between the western and southern parts of the southwestern Cape agricultural region is shown by several other large terrestrial birds, i.e. Blackheaded Heron *Ardea melanocephala*, White Stork *Ciconia ciconia*, Stanley's Bustard *Neotis denhami*, Karoo Korhaan *Eupodotis vigorsii*, and Black Crow *Corvus capensis* (Hockey *et al.* 1989), all of which are common in the southern Cape but are less common or absent in the Swartland.

The count of 1160 Blue Cranes at the Rietpoel roost appears to be the largest single aggregation of this species ever reported. The finding that large numbers of Blue Cranes fly into aquatic roosts after dark emphasises the potential danger of overhead transmission lines situated close to roosts. Such constructions should never be sited close to Blue Crane roost sites. Flights to roosts after dark also have been reported for other crane species (e.g. Alonso *et al.* 1985). The high pitched vocalization heard from some flying cranes at roosts appeared to be given by juvenile cranes flying in groups with adults and may serve as a contact call allowing juveniles and their parents to remain in close proximity in these assemblages of conspecifics.

Appendix 6.1 The availability of six different habitat types in the southern Cape and their use by Blue Cranes. The habitat availability data are presented separately for each month and the information on habitat use by Blue Cranes is presented separately for every month during which data were collected. The sample sizes in the final column refer to the number of data points used in assessing habitat availability, and the number of Blue Crane individuals and groups recorded during each month, respectively.

Month	% cult. pastures	% harv. cereal	% grow. cereal	% plough. fields	% nat. veg.	% misc.	n=
FEBRUARY							
Avail. habitat	**48,6%**	**21,4%**	**0,1%**	**10,4%**	**11,4%**	**8,0%**	**1119**
Use 1991-inds	14,2%	83,3%	-	2,5%	-	-	240
Use 1991-grps	*31,6%*	*60,5%*	-	*7,9%*	-	-	*38*
MARCH							
Avail. habitat	**47,8%**	**19,4%**	**-**	**12.3%**	**11,6%**	**8,9%**	**2086**
Use 1990-inds	35,3%	49,2%	-	14,3%	1,2%	-	252
Use 1992-inds	14,7%	61,3%	-	24,0%	-	-	217
Use 1990-grps	*40,0%*	*46,6%*	-	*6,7%*	*6,7%*	-	*30*
Use 1992-grps	*31,6%*	*50,0%*	-	*18,4%*	-	-	*38*
APRIL							
Avail. habitat	**41,9%**	**10,8%**	**1,0%**	**23,7%**	**11,5%**	**11,1%**	**1318**
Use 1993-inds	25,0%	65,5%	-	9,5%	-	-	432
Use 1993-grps	*29,3%*	*51,2%*	-	*19,5%*	-	-	*41*
MAY							
Avail. habitat	**41,4%**	**10,9%**	**1,4%**	**26,6%**	**11,5%**	**8,2%**	**1336**
Use 1991-inds	37,9%	31,2%	0,9%	30,0%	-	-	641
Use 1991-grps	*36,1%*	*25,0%*	*2,8%*	*36,1%*	-	-	*36*
JUNE							
Avail. habitat	**46,8%**	**0,5%**	**23,0%**	**8,0%**	**11,7%**	**10,0%**	**1384**
Use 1989-inds	7,0%	-	90,7%	2,3%	-	-	572
Use 1992-inds	20,1%	-	71,5%	8,4%	-	-	676
Use 1989-grps	*26,1%*	-	*56,5%*	*17,4%*	-	-	*23*
Use 1992-grps	*38,6%*	-	*52,3%*	*9,1%*	-	-	*44*
JULY							
Avail. habitat	**45,2%**	**2,4%**	**33,1%**	**0,6%**	**11,1%**	**7,6%**	**2080**
Use 1989-inds	56,3%	-	10,2%	33,5%	-	-	531
Use 1990-inds	99,1%	0,2%	0,7%	-	-	-	548
Use 1991-inds	84,8%	-	12,9%	2,3%	-	-	599
Use 1993-inds	97,1%	-	2,9%	-	-	-	444
Use 1989-grps	*72,7%*	-	*15,2%*	*12,1%*	-	-	*33*
Use 1990-grps	*91,7%*	*2,8%*	*5,5%*	-	-	-	*36*
Use 1991-grps	*80,0%*	-	*14,3%*	*5,7%*	-	-	*35*
Use 1993-grps	*95,5%*	-	*4,5%*	-	-	-	*22*
AUGUST							
Avail. habitat	**45,9%**	**-**	**31,7%**	**1,4%**	**12,6%**	**8,4%**	**1244**
Use 1992-inds	79,2%	-	0,3%	13,8%	6,7%	-	1181
Use 1993-grps	*84,2%*	-	*5,3%*	*7,9%*	*2,6%*	-	*38*

Appendix 6.1 (cont.)

Month	% cult. pastures	% harv. cereal	% grow. cereal	% plough. fields	% nat. veg.	% misc.	n=
SEPTEMBER							
Avail. habitat	**44,8%**	-	**35,1%**	**2,3%**	**11,1%**	**6,7%**	**984**
Use 1988-inds	92,5%	-	4,7%	1,4%	1,4%	-	294
Use 1988-grps	*76,9%*	-	*11,5%*	*7,7%*	*3,9%*	-	*26*
NOVEMBER							
Avail. habitat	**51,4%**	**24,5%**	**1,9%**	**3,6%**	**10,2%**	**8,4%**	**2230**
Use 1990-inds	70,7%	29,3%	-	-	-	-	266
Use 1991-inds	48,4%	50,2%	0,9%	0,5%	-	-	221
Use 1990-grps	*40,0%*	*60,0%*	-	-	-	-	*50*
Use 1991-grps	*42,8%*	*51,4%*	*2,9%*	*2,9%*	-	-	*35*
DECEMBER							
Avail. habitat	**44,9%**	**27,8%**	**0,5%**	**5,1%**	**10,9%**	**10,8%**	**1360**
Use 1992-inds	38,2%	57,8%	2,0%	2,05%	-	-	102
Use 1992-grps	*34,7%*	*61,2%*	*2,1%*	*2,05%*	-	-	*49*

CHAPTER 7

MORPHOMETRICS, SEX RATIO, MOULT AND STOMACH CONTENTS OF BLUE CRANES *ANTHROPOIDES PARADISEUS* IN THE SOUTHWESTERN CAPE PROVINCE, SOUTH AFRICA

CHAPTER 7

MORPHOMETRICS, SEX RATIO, MOULT AND STOMACH CONTENTS OF BLUE CRANES *ANTHROPOIDES PARADISEUS* IN THE SOUTHWESTERN CAPE PROVINCE, SOUTH AFRICA

SUMMARY

The morphometrics, sex ratio, remigial moult and stomach contents of 42 poisoned Blue Cranes Anthropoides paradiseus *in the southwestern Cape Province which died in August were examined. The sex ratio was exactly 1:1. Three birds were juveniles (first-year birds) and two appeared to be second-year birds. Males averaged larger than females in all dimensions but there was wide overlap between the sexes in measurements. None of the birds were in active moult during this winter non-breeding period. Primaries appear to be moulted simultaneously and secondaries progressively but the pattern of secondary moult was complex and variable between individuals. There appeared to be differences between the sexes in patterns of secondary moult. Only vegetable matter was found in the stomachs in this winter sample, along with large amounts of grit.*

7.1) *Introduction*

Cranes are monogamous and therefore can be expected to show sex ratios that do not differ significantly from parity but cranes do not show obvious sexual dimorphism in plumage and therefore data on sex ratios can be obtained only from specimen material (Johnsgard 1983). Detailed sex ratio data, however, exist only for the Sandhill Crane *Grus canadensis*. The assessment of sex ratios in this species usually is based on studies of hunted birds and is confounded by the apparently higher vulnerability of males to hunting. The only study based on specimens from natural mortality (Tacha & Vohs 1984) found that the sex ratio is slightly but significantly biased towards females.

There are relatively few published measurements of Blue Cranes *Anthropoides paradiseus* and, although females are thought to be slightly smaller than males as in all other species of cranes, the magnitude of age and intersexual differences has not been described (Johnsgard 1983, Maclean 1993, Urban *et al.* 1986).

The flight feathers of most cranes reportedly are moulted simultaneously, resulting in a flightless period (Johnsgard 1983). Such moult does not occur annually in each individual but only every second to fourth year (Stresemann & Stresemann 1966, Cramp & Simmons 1980). This moult pattern and associated flightlessness is found in members of at least 13 families (Stresemann & Stresemann 1966). The condition is associated with high wing loading, which militates against gradual moult of the flight

feathers, and use of aquatic habitats, which allows for predator avoidance during the flightless period (Heinroth & Heinroth 1958, Stresemann & Stresemann 1966).

Cranes are omnivorous, eating both vegetable and animal (mainly invertebrate) matter (Johnsgard 1983). They are largely vegetarian, however, and their carnivorous habits appear to have been over-estimated, or at least over-stressed, by some observers. In fact, an examination of the species accounts in Johnsgard (1983) confirms that vegetable matter predominates in at least 13 species. Only two species, the Whooping *G. americana* and Redcrowned *G. japonensis* Cranes, reportedly favour invertebrates, although both also take plant material. In the former species, diet has been studied only on the nonbreeding grounds (Hunt & Slack 1989), while the diet of the latter is poorly known and requires further study to confirm the alleged preference for animal food. Cranes chicks of all species, however, appear to be fed largely on small invertebrates (Johnsgard 1983).

7.2) *Aims*

The aims of this study were to examine morphometric variation, sex ratio, moult of the remiges, and stomach contents in a sample of poisoned Blue Cranes.

7.3) *Methods*

The carcasses of 42 of 45 Blue Cranes which were killed when illegally poisoned by an unknown person near Rietpoel (34° 15'S, 19° 45'E) in the southwestern Cape Province on 26 August 1991 were examined. They died from ingesting maize kernels soaked in diazinon, a sheep dip (A.H. Scott pers. comm.). The examination was made in collaboration with Dr P.G. Ryan of the Percy FitzPatrick Institute of African Ornithology at the University of Cape Town. These 42 specimens had been donated to the South African Museum, Cape Town, and were offered to DGA for analysis. All of the carcasses were fresh and intact, except for five which had their stomachs removed for toxicological analysis prior to this examination.

Juveniles, i.e. cranes of less than one year old, were identified by their less 'bulbous' head shape, uniformly coloured heads (adults have a pale crown), their lack of elongated inner tertials (Urban *et al.* 1986, DGA pers. obs), and by the presence of buffy feathers, primarily in the greater, median and lesser coverts, and on the flanks, belly and thighs. The sex of each specimen was determined by examination of the gonads; only one specimen could not be sexed.

All of the carcasses were weighed and measured. Masses were measured to the nearest 50 g using a 10 kg Pesola spring balance. The masses of the five individuals which had their stomachs removed prior to examination were not incorporated in the results. The following morphological characters were measured to the nearest 1 mm

using a stoppered wing rule: wing length (flattened chord from the carpal joint to the tip of the longest primary), the length of the longest tertial (from the feather insertion point to the tip), tail length (from the uropygial gland to the tip of the longest rectrix), and tarsus length (from the notch on the posterior side of the tibiotarsal joint to the anterior distal edge of the flexed tarsus, i.e. tarsometatarsus). Wingspans were measured to the nearest 2 mm using a tape measure, doubling the distance from the midline of the back to the tip of the longest primary on the fully stretched wing (after Pennycuick 1989). Vernier calipers were used to measure the following characters to the nearest 0,1 mm: total head length (from the occiput to the tip of the upper mandible), bill depth (measured vertically at the proximal edge of the nares), and two measures of bill length, one from the proximal edge of the nares to the tip of the upper mandible and the other from the start of the feathering on the mid-line to the tip of the bill. All measurements were made by one observer (PGR).

The primary and secondary feathers of the outstretched right wing were examined for moult. Each feather was classified as 'old', 'just completed' ('very new'), 'new' or of unknown age.

The stomach contents of 36 of the 37 intact carcasses were examined. Stomach contents were sorted into food items and grit, and were then washed, counted and weighed (to the nearest 0,01 g). Blotting paper was used to remove excess moisture from food items which were then weighed while still damp, i.e. wet weight, while grit was dried in an oven before being weighed. Pieces of grit were too numerous in each stomach to be individually counted and therefore 100 pieces were chosen at random from each stomach and weighed. This weight was then compared with the total weight of grit in each stomach to estimate the total number of pieces. The length and width of 50 pieces chosen at random from all the combined stomach contents were measured to the nearest 0,01 mm using vernier calipers to assess the mean size of grit pieces.

7.4) *Results*

Three individuals were juveniles, assumed to be about 9-12 months old; peak egglaying in this species occurs between September and December (Siegfried 1985, Chapter 5). Two of the 'adults' retained a few juvenile (buffy-tipped) feathers and probably were second-year birds.

Sex ratio

The sex ratio among the 38 adults which could be sexed (out of 39) was exactly 1:1 (19 males and 19 females). The three juveniles were thought to be females although their gonads were poorly developed.

Morphometrics

Among the adult Blue Cranes, males averaged larger than females in all dimensions (Table 7.1). The differences between sexes in bill length (both from the nares and from the start of the feathering) and longest tertial length were not significant (Table 7.1). The differences between sexes in mass, wing length, wingspan, tarsus length, total head length, and bill depth were significant. Mass, however, tended to have the greatest coefficient of variation and probably varies seasonally to a greater extent than linear measurements of size. The difference between sexes in tail length was near significant ($P<0,1$). There was considerable overlap between male and female size ranges (Figure 7.1), which makes univariate measures inadequate for predicting the sex of birds from external measurements. Discriminant function analysis (Sneath & Sokal 1973) was used to identify multivariate predictors of sex. Based on five variables: DF=0,29225 total head length - 0,32250 bill length (measured from the nares) + 0,01117 wing length + 0,00789 tarsus length + 0,00621 tail length., where positive DF values indicate males, negative DF values indicate females (group centroids: male 0,76, female -0,76). This technique, however, misclassified 26% of males and 11% of females. The likelihood of misclassifying birds of unknown sex would be even greater. Increasing the number of variables had little influence on the predictive ability of DF values. It is of interest that males appear to have relatively short bills compared with females, hence the negative factor loading on bill length.

Despite small sample sizes, juvenile Blue Cranes averaged smaller than adults (Table 7.1) suggesting that they are not fully grown at almost one year of age. All three juveniles were thought to be females and therefore are best compared with adult females. The greatest differences were in mass, with the three juveniles averaging 80-99% of adult female mean masses, and in the lengths of the tail and longest tertial (Table 7.1).

Moult

Full details of the remigial (primaries and secondaries) moult of the 42 birds are given in Appendix 7.1. None of the 42 birds examined showed active moult of the remiges, i.e. missing or growing feathers. All birds had 10 primaries and 14-18 secondaries (14-one second-year bird, 16-nine birds, 17-13 birds, 18-11 birds, not counted-eight birds). All birds had primaries of one age except for two birds which had primaries of two ages, an adult female (no. 16) and an adult male (no. 32). In these two individuals the outermost primaries were distinctly newer than the rest.

Secondaries of two or three different ages were found in 73% (27/37) of adults and both birds thought to be in their second year. The remaining 27% (10/37) of adults and the three juvenile birds had secondaries of one age. Three birds had secondaries of

Table 7.1 Means, standard deviations and ranges of various Blue Crane morphometric characters based on a sample of 41 birds from the southern Cape Province, with comparison between the sizes of adult males, adult females and juveniles. Sample sizes equal 19 for males, 19 for females and three for juveniles, except for mass where n = 18 males and 15 females. All measurements are in mm except for mass which is in grams.

	Males **mean** (range)	*S.D.*	Females **mean** (range)	*S.D.*	t-test	Juvs **mean** (range)	*S.D.*
Mass	**5094** (4220-5820)	*486,1*	**4645** (4300-4950)	*192,8*	$P<0,01$	**3923** (3820-4100)	*125,5*
Wing	**572,1** (544-628)	*22,75*	**550,3** (521-586)	*15,24*	$P<0,01$	**533,0** (526-547)	*9,90*
Wingspan	**2101** (1916-2290)	*104,5*	**1988** (1830-2164)	*95,3*	$P<0,01$	**1892** (1840-1956)	*48,1*
Longest tertial	**705,1** (535-760)	*47,87*	**687,7** (615-750)	*33,34*	n.s.	**553,7** (521-602)	*34,87*
Tail	**249,8** (223-280)	*13,32*	**242,2** (220-267)	*10,90*	$P<0,1$	**202,7** (195-209)	*5,79*
Tarsus	**253,0** (220-279)	*16,08*	**241,7** (211-258)	*13,48*	$P<0,05$	**234,3** (231-240)	*4,03*
Total head	**176,5** (157,6-186,2)	*5,77*	**171,8** (164,2-181,8)	*4,96*	$P<0,05$	**166,7** (162,1-172,4)	*4,28*
Bill length (from nares)	**73,6** (59,6-79,3)	*4,60*	**72,9** (65,5-79,3)	*3,33*	n.s.	**72,7** (68,4-76,0)	*3,18*
Bill length (from feathering)	**92,1** (77,5-98,6)	*4,35*	**89,4** (71,5-99,0)	*6,15*	n.s.	**84,7** (80,7-91,1)	*4,59*
Bill depth	**23,3** (21,7-25,0)	*0,79*	**22,3** (20,4-23,5)	*0,67*	$P<0,001$	**21,4** (19,8-22,5)	*1,16*

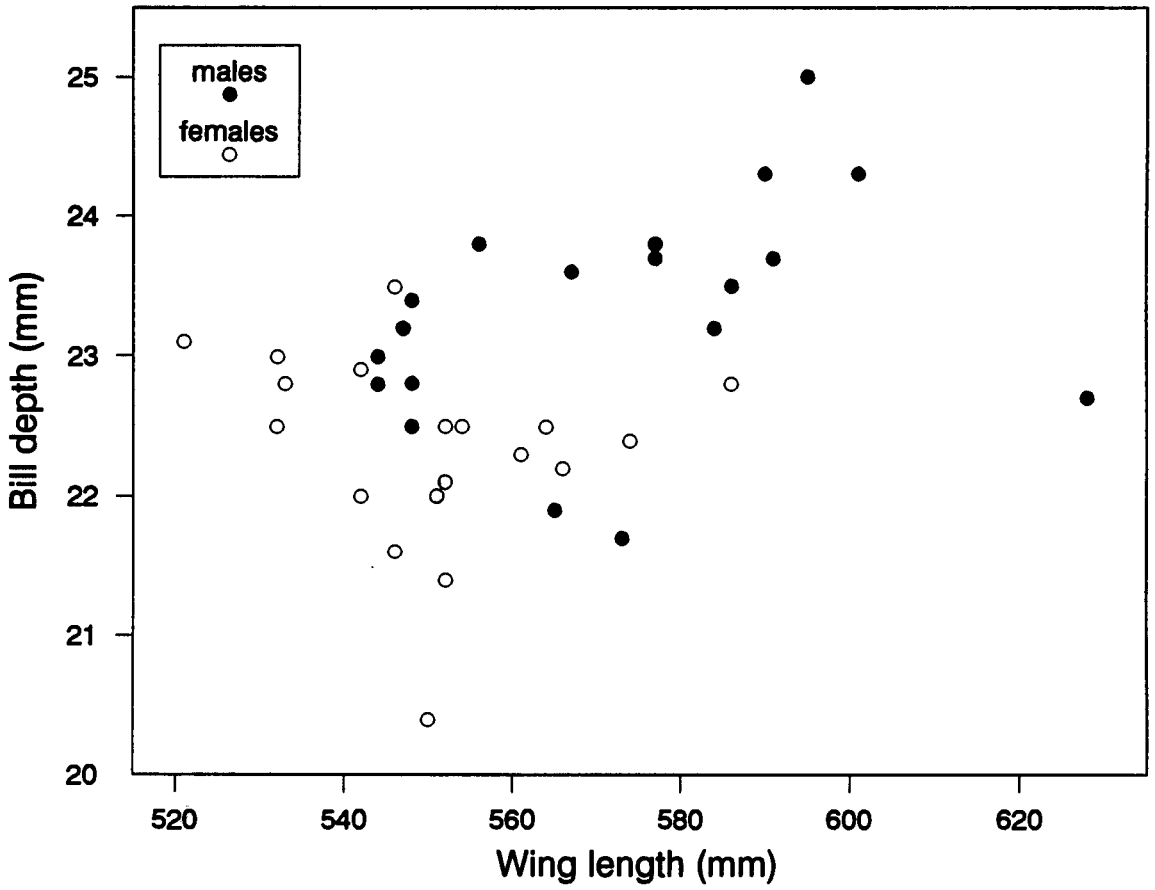

Figure 7.1 Biplot of bill depth and wing length among adult male and female Blue Cranes.

three different ages, two adult females (nos 9 and 15) and one adult male (no. 31). Each had a single secondary classified as just complete, the remainder being new and of uncertain age. In two cases the just complete feather was the innermost secondary, while in the third it was secondary number 14 and was flanked by new feathers. In most cases (24/29), of birds with secondaries of different ages, the new or just completed secondaries were not interspersed with older secondaries but were directly adjacent to one another. In addition, these newer secondaries always occupied the most proximal part of the wing, with no older feathers positioned inside of them. The exceptions to this were five adult females (nos 13-17) which had secondaries of different ages interspersed with one another but still with newer secondaries tending to be concentrated in the proximal part of the wing.

A obvious feature was that in birds with secondaries of different ages the newer secondaries were noticeably longer than the older secondaries. This applied to 23 of the 25 birds where secondary length was noted and which had different aged secondaries. The two exceptions were adult females (nos 13 and 15). In no. 13 one new secondary of four was the same length as the older secondaries. This secondary was on the distal part of the wing, well separated from the other three new secondaries which were positioned on the proximal part of the wing. In no. 15 secondaries of three different ages were all of the same length and older and newer secondaries were interspersed and present both distally and proximally.

Among the 36 fully adult birds which could be sexed, there was a significant difference between the sexes in the proportion of birds with secondaries of different ages. A higher proportion of adult females (16/17) had secondaries of different ages than did adult males (11/19; G=4,851, P<0,05, G test). The finding that in birds with secondaries of different ages, only adult females had newer and older feathers interspersed, when compared to adult males, was near significant. Five of 16 adult females with secondaries of different ages had older and newer feathers interspersed, while this was not the case in any of 11 adult males (G=2,795, P<0,1, G test).

Stomach contents

The stomach contents consisted of the maize seeds used to poison the birds, some lucerne leaves, large amounts of grit, and a small proportion of other material, mainly green vegetable matter (Table 7.2, Figure 7.2). Maize was found in all the stomachs except one, which was entirely empty of food and held only grit. The mean mass of maize in the 35 stomachs containing this food type was 6,09g. Many of the seeds in the stomachs were fragmented and the estimated mean number of seeds in each stomach was 16,7. Lucerne leaves were present in 11 stomachs (30,6%). The mean mass of lucerne in each of these 11 stomachs was 1,06g and the mean number of lucerne leaves was

Table 7.2 Details of the stomach contents of 36 Blue Cranes from the southwestern Cape.

Item	Mean no. items/ stomach with item	S.D.	range	Mean mass items/ stomach with item	S.D.	range	No. stomachs with item
Maize	16,7	13,6	1-62	6,09g	5,08g	0,08-22,53g	35 (97,2%)
Lucerne	35,6	44,4	1-164	1,06g	1,20g	0,01-3,73g	11 (30,6%)
Unid. green veg. matter	3,8	5,9	1-20	0,12g	0,17	0,01-0,54g	10 (27,8%)
Small white bulbs	4	-	3-5	0,12g	-	0,10-0,14g	2 (5,6%)
Twigs	3	-	-	0,07g	-	-	1 (2,8%)
Bone fragment	1	-	-	0,07g	-	-	1 (2,8%)
Grit	778,0	221,4	241-1286	27,63g	7,21g	9,81-42,31g	36 (100,0%)

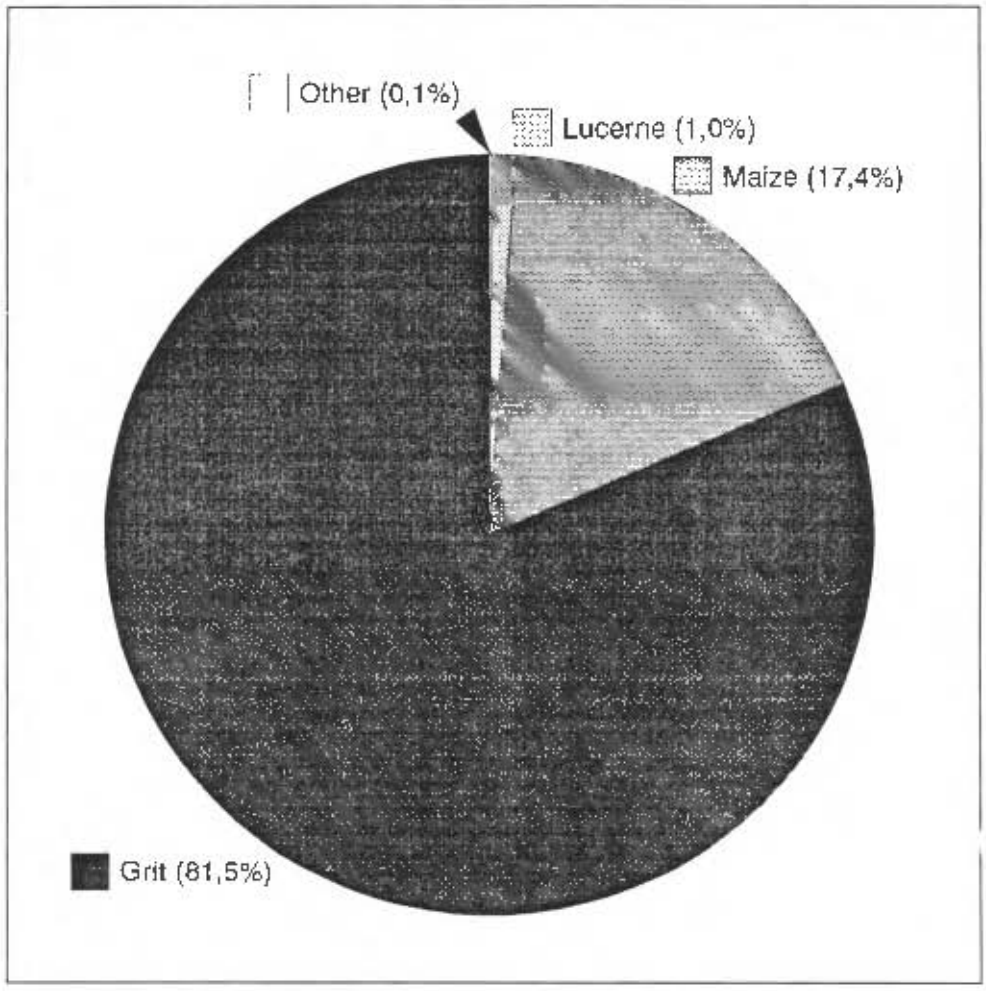

Figure 7.2 Stomach contents of 36 Blue Cranes collected in August in the southern Cape by percentage mass occurrence.

35,6. Grit was present in all stomachs. The mean mass of grit in each stomach was 27,64g and the estimated mean number of grit pieces was 778,0. The mean length of grit pieces was 3,94mm (S.D.=1,15mm; n=50) and the mean width was 2,89mm (S.D.=0,82mm; n=50). The mean length of the ten largest pieces of grit found in all the stomachs combined was 12,18mm (S.D.=2,65mm; maximum 17,74mm; n=10) and the mean width was 7,92mm (S.D.=1,25mm; maximum 11,06mm; n=10).

Little other material was found in the stomachs and its combined mass from all stomachs was only 1,56g, compared with a total mass of 213,01g of maize and 11,61g of lucerne. It consisted of unidentified green vegetable matter (1,18g) found in 10 stomachs, eight small white bulbs (0,24g) found in two stomachs, three twigs (0,07g) found in one stomach, and a small bone fragment (0,07g) found in one stomach. No trace of invertebrate material was found.

No significant differences were found between the stomach contents of adult males and females in mass of maize (U=104; P>0,05; Mann-Whitney U-test), number of maize seeds (U=104,5; P>0,05), proportion of stomachs with lucerne (χ^2=3,702; P>0,05), mass of grit (U=122; P>0,05), and number of pieces of grit (U=118; P>0,05). The difference in the proportion of stomachs containing lucerne, however, approaches significance with 47% (7/15) of female stomachs containing lucerne versus only 18% (3/18) of male stomachs. The amount of lucerne in the stomachs of the females and males with this food item further suggests a sex-related difference in the choice of this food, although sample sizes are too small for meaningful statistical analyses. The mean mass of lucerne in the seven females was 1,45g (S.D.=1,33g; range 0,01-3,73g; n=7) and in the three males was 0,16g (S.D.=0,11g; range 0,01-0,27g; n=3). Although the median mass and number of pieces of grit in female and male stomachs were not significantly different, males had significantly higher variation in the amount of grit in their stomachs (females mean mass grit=26,42g, S.D.=4,62g, range 17,52-36,70g, n=15, males mean mass grit=28,55g, S.D.=8,84g, range 9,81-42,31g, n=18, F=3,66, P<0,01, F-test; females mean number grit pieces=745,3, S.D.=152,3, range 496-983, n=15, males mean number grit pieces=790,5, S.D.=257,1, range 241-1286, n=18, F=2,85, P<0,05).

7.5) *Discussion*

The data set upon which this study is based is particularly valuable as the circumstances in which the birds were obtained means that seasonal, annual and regional variation in the characters examined is minimized. The observed proportion of juveniles in the sample (3/42, 7,1%) agrees well with other counts of the adult:juvenile ratio in the study area (see Chapter 5). This and the even sex ratio suggest that the sample is representative of the southern Cape population.

Sex ratio and morphometrics

The accurate sexing of juvenile Sandhill Cranes can be difficult (Krapu & Johnson 1990) and therefore the suggestion that the three juvenile Blue Cranes were females should be regarded as tentative. The finding that the juveniles had not reached full size despite being almost one year old agrees with similar findings for the Sandhill Crane (Tacha, Vohs & Warde 1985). Using linear discriminant functions estimated from leg length, bill length and body weight, Nesbitt *et al.* (1992) were able to predict the sex of Sandhill Crane individuals with a misclassification rate that did not exceed six percent. The possibly relatively shorter bills in male Blue Cranes could be genetic or result from sex-related foraging differences affecting the amount of wear on the bill tip (*cf.* Hulscher 1985, Hulscher & Ens 1992).

Moult

Simultaneous moult of the remiges was suggested as probable in at least the Eurasian *G. grus*, Whooping, Redcrowned, Sarus *G. antigone*, Whitenaped *G. vipio*, Blue, and Siberian *G. leucogeranus* Cranes as early as the end of the last century (Blaauw 1897, in Johnsgard 1983). In addition, it has been recorded subsequently in the Hooded *G. monachus* (Johnsgard 1983), Wattled *Bugeranus carunculatus* (Douthwaite 1974, Hustler *et al.* 1992), and Sandhill (Littlefield 1970) Cranes. Flightlessness apparently is regular in at least the Eurasian, Hooded, Whooping, Redcrowned, Sarus, Whitenaped, Blue, Wattled, and Siberian Cranes, but does not occur in the Demoiselle Crane *A. virgo* and the Black *Balearica pavonina* and Grey *B. regulorum* Crowned Cranes (Moody 1932, in Johnsgard 1983, Douthwaite 1974, Cramp & Simmons 1980, Erickson & Derrickson 1981, Flint & Kistchinski 1981). The lack of flightlessness in the Demoiselle Crane has been attributed to its use of dryland habitats (Heinroth & Heinroth 1958). Johnsgard (1983) suggests that the same may apply to the crowned cranes. Although crowned cranes rely on wetland habitats for breeding, they frequently forage in dry habitats, sometimes relatively distant from aquatic areas (Pomeroy 1987, Gichuki & Gichuki 1991). However, the same also applies to many other species of cranes. Moult of the remiges in the Demoiselle Crane and the crowned cranes follows no clear sequence and would appear to be a derived trait from a previous simultaneous moult condition (Stresemann & Stresemann 1966).

Most information on flightless moult in cranes comes from captive birds and little information exists about wild individuals (Stresemann & Stresemann 1966). This apparently is due to the secretiveness of moulting cranes. Museum specimens of individuals with growing remiges are extremely uncommon for species with simultaneous moult (Stresemann & Stresemann 1966). These authors examined 30

museum skins of Australian Cranes *G. rubicunda* and found six of these to have primaries of non-uniform age. This is indirect evidence against simultaneous moult of all the remiges. Nevertheless flightlessness has been confirmed in the wild for several species, including the Eurasian (Cramp & Simmons 1980), Whooping (Erickson & Derrickson 1981), Blue (Blaauw 1897, in Walkinshaw 1949), Wattled (Douthwaite 1974, Hustler *et al.* 1992), Siberian (Flint & Kistchinski 1981), and Sandhill (Littlefield 1970) Cranes.

It is surprising that the Blue Crane has a flightless period because, like the congeneric Demoiselle Crane (Krajewski 1989), it inhabits dry areas. It would appear to be the only crane species allegedly with simultaneous moult that is not primarily an aquatic species. Records of flightlessness in Blue Cranes come from both captive and wild individuals (Blaauw 1897 in Walkinshaw 1949) and therefore cannot be attributed merely to unnatural moult patterns in captive birds, which is a relatively widespread phenomenon (Stresemann & Stresemann 1966).

Much variation was found in the moult of remiges from a large sample of Sandhill Cranes (Lewis 1979c). In fact, only a minority (41%; n=108) had remiges all of the same age. This study found that moult is descending in both the primaries and secondaries and does not occur in numerical sequence. Two other studies also have found that Sandhill Cranes frequently have remiges of different ages (Layne 1981, Nesbitt *et al.* 1987). Therefore, simultaneous moult of all the remiges may not be as common in wild cranes as reports from zoos initially would suggest. It is possible that many wild birds moult in a manner intermediate between total loss of the remiges and progressive moult, perhaps with large intra- and interspecific differences. This probably allows the retention of at least some flying ability at all times.

Moult of the remiges in cranes also has attracted attention as it may reveal clues as to the age, sex and breeding status of individuals (Lewis 1979c). In particular it has been suggested that adult breeding individuals may be characterized by remiges of one age compared to non-breeding adults which may have remiges of more than one age.

Remigial moult in most cranes, simultaneous or otherwise, appears to occur during the breeding season in at least the Eurasian (Stresemann & Stresemann 1966, Cramp & Simmons 1980, Prange & Mewes 1991), Whooping (Erickson & Derrickson 1981), Demoiselle (Stresemann & Stresemann 1966, Kovshar 1987), Siberian (Flint & Kistchinski 1981), and Sandhill (Layne 1981) Cranes. A possible exception is the Wattled Crane where flightlessness was observed during January-April at both the Kafue Flats in Zambia (Douthwaite 1974) and in Zimbabwe (Hustler *et al.* 1992), where breeding normally occurs during April-September. Only a relatively small proportion of breeding pairs attempt to breed every year in this species (e.g. Douthwaite 1974),

however, and the breeding season is poorly defined and egglaying can occur in any month of the year (e.g. Tarboton 1984).

The results presented here suggest that active moult in the Blue Crane does not occur during the winter and probably is restricted to the summer (breeding) period. Only two individuals had primaries of different ages, suggesting that primary moult usually, but not invariably, is simultaneous. Further evidence for simultaneous moult of the primaries comes from a field case study. A nest site in the southern Cape was visited on 9 December 1992 and no moulted remiges were noted in the area around the nest. When next visited two days later nine moulted primaries (six from the left wing and three from the right wing) were found in the area immediately surrounding the eggs. The size, colour and state of wear of these feathers suggested that they all came from the same individual. By contrast, the large proportion of birds in the poisoned sample with secondaries of different ages suggests that secondary moult usually is not simultaneous. The pattern and direction of moult in the secondaries follows no clear sequence and appears variable between individuals.

It has been suggested (G.W. Archibald in Lewis 1979c) that breeding cranes (mated adults) may be identified by remiges all of the same age, due to simultaneous moult during incubation, while non-breeding cranes (unmated 'sub-adults') may be identified by remiges of different ages, due to sequential moult in these individuals. This suggestion was refuted by Lewis (1979c) for the Sandhill Crane who found breeders with both evenly and unevenly aged wings. If Archibald's (*op. cit.*) suggestion is correct then the 10 of the 37 (27%) apparently fully adult Blue Cranes in this study which had even aged wings would have been breeders in the previous season. However, eight of these were males, one was of unknown sex and only one was a female. The data presented here suggest that even and uneven aged wings are sex-related in the Blue Crane (but with overlap between the sexes in this character). In addition, these data suggest that interspersion of older and newer secondaries may be restricted to females and could be useful in diagnosing the sex of live individuals, although most females resembled males in this character. In the Sandhill Crane, by contrast, no sex-related differences in moult were found (Lewis 1979c).

The finding that a large proportion of the birds had secondaries of different lengths is interesting. It is possible that the first secondaries grown by juveniles are shorter than those grown subsequently. Shorter remiges in juveniles compared with adults occurs in some gamebirds (Phasianidae, e.g. Mueller & Seibert 1966, in Johnsgard 1986). If this is the case in Blue Cranes, then birds with secondaries of different lengths could be in transitional plumage between juvenile and adult secondaries, i.e. 'immatures' or 'sub-adults'. This need not mean that they are in their second year as the loss of all the juvenile secondaries may require several years before completion. Of the 39 cranes

classed as adults or second-year birds, 59% (assuming that the seven birds for which the length of the secondaries was not noted had feathers of equal lengths) had secondaries of unequal lengths and therefore could be 'immatures'. This proportion may seem high but is possible in the light of the high proportion of non-breeding birds found in the Blue Crane and other members of the family (see Chapters 1 and 5).

Clearly more data on moult in Blue Cranes (and other members of the family) are required, particularly from other times of the year and from individuals of know age and breeding status. For this reason the raw data from this study have been presented in full (Appendix 5.1) to facilitate comparisons with future studies. It was unfortunate that the moult of both wings was not recorded as Lewis (1979c) found that 49% of Sandhill Cranes had dissimilar moult patterns on opposite wings.

Diet

All species of cranes, except for the Siberian Crane, occasionally or regularly, indeed during some periods virtually exclusively, feed on crops, e.g. wheat, maize, rice, sorghum, barley, oats, rye, sunflowers, peanuts, soya beans, beans, peas, cabbages, spinach, lucerne, etc. (Pomeroy 1980, Johnsgard 1983, Reinecke & Krapu 1986, Alonso & Alonso 1991, Fulin 1991, Youhui 1991). Cereal crops are particularly favoured and the birds usually glean fallen seeds in harvested fields. Exploitation of these unnatural foods is most common during the nonbreeding period in most wetland dependent species. The habit has obvious economic, conservation and management implications.

Detailed dietary analyses exist only for the Sandhill Crane. One study (Mullins & Bizeau 1978) on the diet of this species on its breeding grounds, drawn from gizzard contents, found that natural plant material comprised 73% by volume and the remaining 27% consisted of invertebrate matter. Another study of diet during the nonbreeding season (Reinecke & Krapu 1986), based on gut contents, found that plant material comprised 97% by dry weight, exclusively cultivated maize, and invertebrates 3%. This latter study found that birds foraged for prolonged periods in natural grasslands and lucerne fields to obtain the relatively small proportion of invertebrates consumed, which they suggest are essential to compensate for the protein and calcium deficiencies in maize. In addition, they found that the birds ate small amounts of lucerne shoots, which also are rich in protein. Mixed farming of crops (cultivated maize) and livestock (natural and lucerne grazing lands) therefore was important for providing suitable foraging habitat for this species.

A further study on the nonbreeding diet of Sandhill Cranes from another locality (Hunt & Slack 1989), based on an analysis of faecal samples, found vegetable matter to comprise 98% by volume and invertebrate matter 2%. Although the plant material

consumed consisted almost entirely of natural plants (amaizes *Quercus virginiana* and wolfberry *Lycium virginiana*), these authors state that cultivated grains are the major diet in the region and that the birds they collected, which came from a protected wetland reserve, temporarily visited the reserve to feed on natural vegetation rich in nutrients (ascorbic acid, iron, calcium, and amino acids) which are absent from maize, the main dietary component. These studies suggest that the heavy reliance of cranes on cultivated crops, which are poor in certain nutrients, could have significant physiological consequences for these birds.

The data from the Blue Crane stomach contents are of limited value due to the artificial circumstances surrounding the ingestion of the main food item (maize). It is of interest that no animal food was found. Data are required on the more natural winter and summer diets, particularly as to whether invertebrates are eaten in the summer (*cf.* Mullins & Bizeau 1978). The large grit loads in themselves are strongly suggestive of a mainly vegetarian diet (Schifferli 1985), at least during the winter, non-breeding period. The larger amounts of lucerne and the higher proportion of stomachs with this food item in females compared with males prompts the speculation that the females were selecting this protein-rich food source during this pre-breeding period (*cf.* Reinecke & Krapu 1986).

Appendix 7.1 Details of the moult of the primaries and secondaries of the right wing of 42 Blue Cranes. The first column provides details of the specimen number, age (ad-adult, 2yr-second year, juv-juvenile, i.e. first year) and sex (f-female, m-male, ?-unknown). The second column (Prim.) provides details on the primaries, all of which were of one age except for specimens 16 and 32, where the most distal feather/s were newer than the remainder. The final columns present details of the secondaries, numbered from the most distal secondary, i.e. towards the body. Number codes: 4=just complete, i.e. very new, 5=new, 8=uncertain, 0=old. Entries in italics denote secondary feathers that were 'long' in comparison to the other secondaries. In some cases all the secondaries were judged to be 'long' in a wing with even-aged secondaries.

No./ Age/ Sex	Prim.	Secondaries																	
	•	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 ad f	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5*+		
2 ad f	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	
3 ad f	5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*
4 ad f	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*		
5 ad f	0	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	
6 ad f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*5*	*5*	*5*
7 ad f	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*5*
8 ad f	0	0	0	0	0	0	0	0	0	0	0	0	0	*5*	*5*	*5*	*5*		
9 ad f	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*4*	*5*	*5*	*5*	
10 ad f	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*5*	*5*	*5*		
11 ad f	8	8	8	8	8	8	8	8	8	8	8	8	5	5	5	5	5	*5+*	
12 ad f	0	0	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	
13 ad f	0	8	5	8	8	8	8	8	8	8	8	8	8	5	8	5	5		
14 ad f	0	8	8	8	8	8	8	8	8	*5*	8	*5*	*5*	*5*	*5*	*5*	*5*	*5*	
15 ad f	0	*5*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*5*	*8*	*5*	*5*	*5*	*5*	*5*	*5*	*4*	
16 ad f	$0^{8}5^{2}$	8	8	8	8	5	5	5	8	8	8	5	5	5	5	5	5	*5*	*5+*
17 ad f	0	8	5	8	5	8	5	8	5	5	5	5	5	5	5	5	*5+*		
18 ad m	5	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5**		
19 ad m	5	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5**		
20 ad m	5	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
21 ad m	5	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
22 ad m	8	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8**		
23 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8*+		
24 ad m	8	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*		
25 ad m	8	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*		
26 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5	5		
27 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*
28 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*		
29 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5	*5*	*5*
30 ad m	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5	*5*	*5*
31 ad m	0	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*4*	
32 ad m	$0^{9}5^{1}$	8	8	8	8	8	8	8	8	8	8	8	8	8	5	5	5	*5+*	
33 ad m	0	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*5*	
34 ad m	0	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*5*	
35 ad m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	*5*	*5+*
36 ad m	0	0	0	0	0	0	0	0	0	0	0	0	*5*	*5*	*5*	*5*	*5*	*5*	*5*
37 ad ?	8	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8**		
38 2yr f	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*			
39 2yr f	8	8	8	8	8	8	8	8	8	8	8	8	8	8	*5*	*5*	*5*	*5*	

Appendix 7.1 (cont.)

No./ Age/ Sex	Prim.	Secondaries																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
40 juv f	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5*		
41 juv f	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5*		
42 juv f	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5+	

* number of secondaries not counted
+ differences in lengths of secondaries not noted

CHAPTER 8

THE CONSERVATION STATUS OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS* IN SOUTH AFRICA

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THE CONSERVATION STATUS OF THE BLUE CRANE *ANTHROPOIDES PARADISEUS* IN SOUTH AFRICA

SUMMARY

Road counts of Blue Cranes Anthropoides paradiseus *made during 1965-1966 and 1988-1993 in the Karoo and fynbos biomes of the Cape Province were compared. There was no evidence for a decrease in the Karoo and a substantial increase in Blue Cranes has occurred in the crop farming regions of the southern Cape (fynbos biome) between the two time periods. Examination of the road counts in the southern Cape within the period 1988-1993 show no evidence for any change in numbers during a four and half year period. A review of published literature statements on the conservation status of the Blue Crane suggest a major decrease in the grassland biome. This has been attributed to intentional and inadvertant poisoning in crop farming areas. Know incidents of poisoning from throughout South African are reviewed. It is unclear why Blue Cranes have thrived in the crop farming areas of the southern Cape but have decreased in similar parts of the grassland biome, as many poisoning incidents have been reported from the former region.*

8.1) *Introduction*

Cranes are among the most threatened avian taxa. Seven of the world's fifteen species are listed in the International Council for Bird Preservation's (ICBP, now Birdlife International) Checklist of Threatened Birds (Collar & Andrew 1988). The conservation saga of the Whooping Crane *Grus americana* is renowned (see Erickson & Derrickson 1981 for a useful review) and has become a symbol of conservation efforts to preserve threatened species (Blinkley & Miller 1980). The Wattled Crane *Bugeranus carunculatus* is the only African crane listed in the ICBP Checklist, and is one of three crane species occurring in South Africa, the other two being the Grey Crowned *Balearica regulorum* and Blue *Anthropoides paradiseus* Cranes. The conservation status of the Wattled Crane in South Africa has received extensive attention (Geldenhuys 1984, Tarboton 1984, Vernon & Boshoff 1986, Tarboton, Johnson & Barnes 1987, Brooke & Vernon 1988, Johnson & Barnes 1991). The conservation status of the Grey Crowned Crane in various parts of South Africa is discussed by Geldenhuys (1984), Johnson & Barnes (1986), Johnson (1992a), Tarboton (1992a), and Vernon *et al.* (1992).

The major threats to cranes worldwide are habitat destruction and persecution (Archibald *et al.* 1981). Habitat destruction usually comes in the form of the degradation of wetlands and surrounding areas, and can include the impact of

commercial afforestation. Afforestation has been implicated as a threat to the Mississippi Sandhill Crane *G. canadensis pulla*, a critically endangered subspecies (Valentine 1987), and to the Wattled Crane in Zimbabwe, Malawi and the Transvaal (West 1977, in Konrad 1981, Tarboton 1984). Persecution is usually motivated by crop damage and can be of particular concern when poisons are used to kill large numbers of cranes. The Australian Crane *G. rubicunda*, for example, has suffered major mortalities due to poisoning to protect crops (White 1987). Mortality of cranes due to poisoning by farmers in other parts of the world also has been reported for the Eurasian *G. grus*, Blacknecked *G. nigricollis* and Demoiselle *A. virgo* Cranes (Fuzhang & Wenning 1987, Khachar *et al.* 1991, Youhui 1991),

Collisions with overhead transmission lines also are proving to be a significant cause of mortality in many species. In the Redcrowned Crane *G. japonensis* in Japan, 71% (n=245) of known mortalities were due to such collisions before markers were placed on the relevant lines rendering them more visible to flying cranes (Akiyama 1981). This was calculated as 2,1% of all mortalities in adults and 13,1% in juveniles (Archibald 1987). This source of unnatural mortality has been identified as the key factor that retarded the recovery of this species in Japan, until ameliorative measures were implemented (Masatomi 1991). A similar problem exists in Korea (Kyu & Oesting 1981). This source of mortality also has been recorded and considered as potentially serious in the Whooping (Erickson & Derrickson 1981, Kuyt 1987) Australian (White 1987, Goldstraw & Du Guesclin 1991), and Sandhill (Walkinshaw 1956, Tacha *et al.* 1979 in Johnsgard 1983, Windingstad 1988) Cranes. One study of the Eurasian Crane found that eight of 17 adults found dead were killed by colliding with overhead lines (Neumann 1987). In South Africa, at least three Wattled Cranes have died in this way (Berruti 1990, Johnson 1991). Fences also can present hazards to cranes, and mortalities caused by these structures have been recorded in at least the Whooping, Australian and Sandhill Cranes (White 1987, Allen 1990).

Simulation models devised for the management of Sandhill Cranes (Miller *et al.* 1972, Miller & Bodkin 1974) have highlighted the vulnerability of populations of this species to unnatural mortality of adult birds. This vulnerability is due to the species' low reproductive potential. The purpose of their studies was to examine the potential impact of hunting on this crane, but can be extrapolated to other forms of unnatural mortality, such as poisoning and collisions with overhead lines, and to other species of cranes, all of which have similarly low reproductive potentials. A similar model has been produced for the Eurasian Crane, which identifies the potential importance of density-dependent factors, i.e increased reproductive success at reduced densities, in mitigating the effects of increased unnatural mortality of adult cranes (Alonso *et al.*

1991). Unfortunately no data are available on density-dependent population parameters in cranes.

Cranes, however, despite their vulnerability to anthropogenic influences, display remarkable adaptability of man-modified conditions. This includes their ubiquitous use of agricultural foods and foraging habitats, and their ability to adjust their patterns of movements, migrations, and roosting in response to man-made alterations of natural environments (see Chapter 1). Even when breeding, many species show surprising tolerance in nesting close to human activities, e.g. Dwyer & Tanner (1992) for the Sandhill Crane and Archibald (1987) for the Redcrowned Crane. Demoiselle Cranes will even nest in agricultural fields (Kovshar 1987). Other examples include the Eurasian Crane in Sweden and Poland, which has undergone a dramatic increase recently, due to its adapting to breeding near to human activity (Bylin 1987, Dobrowolski & Halba 1987). The Sarus Crane *G antigone* in India (Archibald *et al.* 1981), and the Grey Crowned Crane in Transkei, South Africa (Quicklberge 1989) and in East Africa (Pomeroy 1987) both benefit from co-existence with tolerant local peoples and despite the density of the human populations in these areas. This adaptability provides hope that these birds can be effectively conserved given appropriate conservation management. It has been shown (Masatomi 1991) that even the problem of collisions with overhead lines can be solved by rendering these more visible to flying cranes using markers.

Archibald *et al.* (1981) provide a discussion of practical methods that can be employed in crane conservation. These include the reinforcement of traditional, and cultivation of new, human values, protective legislation and its enforcement, winter feeding (Koga 1981, Ohsako 1987, Swanberg 1987), habitat protection and enhancement, and re-stocking programs.

Aspects of this review were presented in Allan (1992).

8.2) *Aims*

The aims of this study were to:

1) compare recent (1988-1993) road count data from this study in the Karoo and fynbos biomes of the Cape Province with similar data collected by Siegfried (1985) in the same regions during 1965-1966,
2) search for evidence of changes in abundance of the species in the southern Cape during a recent four and a half year period that this population was monitored, and
3) review the published literature on the conservation status of the Blue Crane in South Africa and discuss the relevance of the findings of the present study to knowledge of the conservation status of this crane.

8.3) *Methods*

Siegfried (1985) presents an extensive series of road counts, totalling over 300 000 km, of Blue Cranes in the Cape Province made during 1965-1966. Unfortunately his counts for the Karoo are not directly comparable with those made during this study (see Chapter 3) due to differences in the choice of regions under which the data are presented (see his Figure 1 in Siegfried 1968 and Figure 3.1 in Chapter 3). In order to directly compare the two sets of counts it was necessary to re-analyse those made during this study. All counts made during this study in the areas encompassed by his 'Karoo' and 'Midlands' regions were extracted and divided into these two regions. The data from this study presented under Siegfried's 'Midlands' region were made in parts of the Central Upper, Great and Steytlerville Karoos and those under his 'Karoo' region were made in the remainder of all three of these regions and also in Bushmanland and the succulent Karoo. The data from the Orange Free State (Central Upper Karoo) collected during this study were excluded from this analysis. A comparison between the counts from his 'Southern Cape' and 'South-western Cape' regions and those from the southern Cape and Swartland areas made during this study can be done directly, as the latter areas fall entirely within the former areas (see his Figure 1 in Siegfried 1968 and Figure 3.2 in Chapter 3).

The data from the 15 road counts made in the southern Cape between September 1988 and April 1993 (see Chapter 3) are used here to search for evidence for a decrease in this population during this four and a half year period.

8.4) *Results*

Comparison with road count data from 1965-1966

A comparison of the road count data from 1965-1966 (Siegfried 1985) and from this study is presented in Table 8.1 and Figure 8.1. The information is presented under the regions delineated in the former study (see Methods). In all four regions the number of both individuals and groups counted was higher in this study (1988-1993) than in 1965-1966, substantially so in the 'Southern Cape' and 'South-western Cape' regions, although the 1988-1993 data are few for the latter area. The number of individuals and groups counted per 100 km during 1988-1993 in the Karoo ('Karoo' and 'Midlands' regions combined) was 2,4 and 3,5 times higher respectively than in 1965-1966 (4,4 *vs* 1,8 inds/100 km and 0,7 *vs* 0,2 groups/100 km). The number of individuals and groups counted per 100 km during 1988-1993 in the 'Southern Cape' was 204,0 and 64,0 times higher respectively than in 1965-1966 (0,4 *vs* 81,6 inds/100 km and 0,1 *vs* 6,4 groups/100 km). It is not possible to test these differences statistically but an examination of the simple ratios between the number of individuals counted in the three

Table 8.1 A comparison of the results of road counts of Blue Cranes in the Cape Province made during 1965-66 (Siegfried 1985) and during 1988-1993 (this study). The data are presented according to the regions delineated by Siegfried (1985).

Region	No. km	No. inds	Inds/ 100 km	No. groups	Groups/ 100 km	Source
'Karoo'	33945	147	0,43	41	0,12	Siegfried (1985)
	4964	104	2,10	20	0,40	this study
'Midlands'	62918	1559	2,48	165	0,26	Siegfried (1985)
	3888	284	7,31	40	1,03	this study
'Sthn Cape'	49580	172	0,35	36	0,07	Siegfried (1985)
	8584	7005	81,61	546	6,36	this study
'SW Cape'	42785	29	0,07	7	0,02	Siegfried (1985)
	519	12	2,31	5	0,96	this study

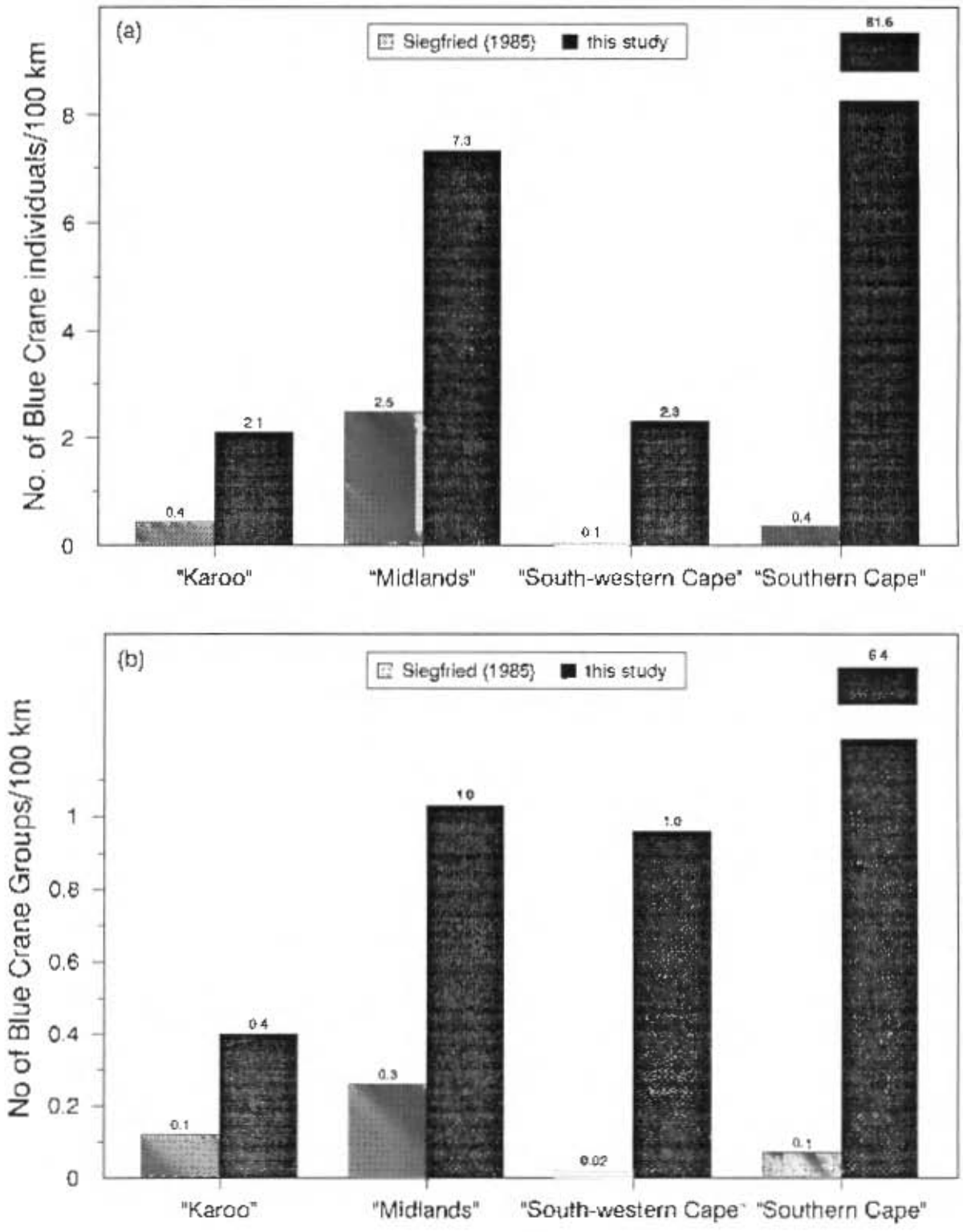

Figure 8.1 The number of Blue Crane individuals (a) and groups (b) counted per 100 km during road transects in 1965-1966 (Siegfried 1985) and 1988-1993 (this study) in the 'Karoo', 'Midlands', 'South-western Cape' and 'Southern Cape' regions of the Cape Province, as delineated by Siegfried (1968, 1985).

regions which have acceptable sample sizes from both time periods ('Karoo':'Midlands':'Southern Cape') shows ratios of 12:76:12 in 1965-1966 and 2:8:90 in 1988-1993. This emphasizes the increased proportion of birds counted in the 'Southern Cape'. This marked change in ratios suggests that methodological differences between the two studies are not responsible for the disproportionately higher number of cranes counted in the 'Southern Cape' in 1988-1993. The recent data from 'South-western Cape' (Swartland) region are few (Table 8.1) but suggest that a similar increase has occurring in this region

Trend in the southern Cape population Sept. 1988-Apr. 1993

The number of Blue Crane individuals counted during road transects in the southern Cape between September 1988 and April 1993 is shown in Figure 8.2. The data from the summer, winter and two intermediate counts (September 1988 and April 1993) have been presented separately in this figure. Although these data are too few for statistical analyses, they suggest no substantial change in the population in this region during the study period.

8.5) *Discussion*

The increased number of Blue Cranes counted in the Karoo during road counts in this study compared with Siegfried's (1985) counts from the 1960's probably is due to differences in methodology. The road counts made during 1988-1993 were done specifically to census large birds, while Siegfied's counts were made during the course of other activities. The 1988-1993 counts were made at relatively slow travelling speeds (*ca* 50 km/hour), while those of Siegfried were probably made at faster speeds. Travelling speed and the number of cranes counted per unit of distance probably are negatively associated. The routes travelled during the 1988-1993 counts also were selected to follow secondary (gravel) roads as far as possible. Siegfried's routes probably were not so selected. It is likely that cranes are less visible from heavily utilized primary (tar) roads, as they probably avoid the areas immediately adjacent to busy roads. During the 1988-1993 study, data from gravel and tarred roads were collected separately and this suggestion can be tested. Combining the data from the Central Upper, Great and Steytlerville Karoos and the southern Cape shows that about twice as many Blue Cranes individuals were seen from gravel roads (50,6 cranes/100 km; 6600 cranes in 13043 km) compared with tarred roads (23,1 cranes/100 km; 832 cranes in 3605 km). This result is highly significant ($\chi^2 = 475$, $P < 0{,}001$, d.f. = 1). In addition, the 1988-1993 counts always employed two observers, while at least some of Siegfried's counts are likely to have been made by single observers.

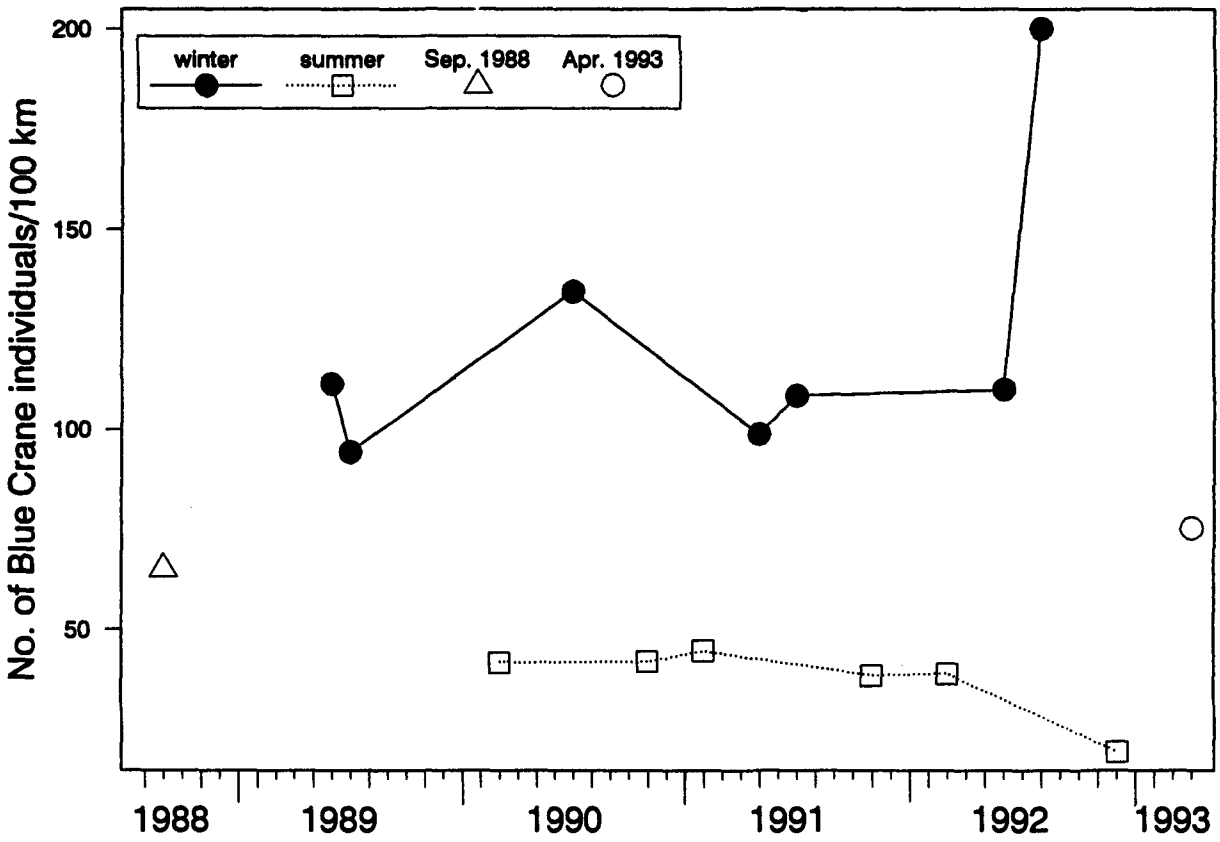

Figure 8.2 The number of Blue Crane individuals counted per 100 km during road transects in the southern Cape between September 1988 and April 1993. The data from the summer, winter and two intermediate counts (September 1988 and April 1993) are presented separately.

The large increase in Blue Cranes noted in the southern Cape (and probably the Swartland) between the two periods, however, almost certainly represents a dramatic increase in the number of cranes in this region. The magnitude of the difference and the change in ratio when compared with the change in ratio in the two Karoo regions renders this interpretation virtually beyond doubt.

Review of South African conservation status

"... I conclude that the blue crane population is healthy throughout South and Southwest Africa and is nowhere endangered." (Van Ee 1981)

*"The blue crane (*Anthropoides paradisea*) is on the endangered list with its distribution and numbers decreasing rapidly."* (Anderson 1990b)

Van Ee (1981) investigated the conservation status of the Blue Crane throughout its range during the mid-1970's and concluded that it was not threatened. The species was not included in either the South Africa Red Data Book - Birds (Brooke 1984) or the African avian Red Data Book (Collar & Stuart 1985). In the late 1980's, however, concern was expressed about its conservation status (e.g. Ledger 1988, Anderson 1990b). This was based on reports of local population decreases and on numerous incidents of poisoning of Blue Cranes throughout their range. The eastern Cape was estimated to support 7000-10 000 birds during the 1960's and about 8000 birds during the early 1980's, decreasing to 1000-2000 birds during the late 1980's (Siegfried 1985, Vernon *et al.* 1992). In Natal, a 90% decrease between 1982 and 1989 was suggested by aerial surveys, with the number of Blue Cranes counted decreasing from 1129 in the 1982 survey to 109 in the 1989 survey (Johnson 1992a). However, the methodology employed in these eastern Cape and Natal censuses was not detailed in these publications and these population estimates are open to question. Additional data from specific localities, however, reinforced this concern. The Verloren Vallei Nature Reserve population near Dullstroom in the Transvaal decreased from 19 pairs to one pair between 1979 and 1989 (Tarboton 1992b). In the Giant's Castle Game Reserve in Natal there were 28 breeding pairs prior to 1970, decreasing to 12 pairs in 1982 and four pairs in 1989 (Johnson 1992a). In the Stormberg, Molteno District in the eastern Cape, a study population decreased from 14 pairs in 1970 to two pairs in 1989 (Vernon *et al.* 1992). In addition, it has decreased in the central and western Transvaal: at Potchefstroom, for example, the species was a common breeding species in the 1860's, whereas it is now scarce and localised there (Tarboton, Kemp & Kemp 1987). In the Transkei, Quickelberge (1989) and Vernon *et al.* (1992) suggest that it has decreased

dramatically since the early 1900's. The status of the species in Transkei, Lesotho and Swaziland is discussed further in Chapter 2.

Statements to the effect that the Blue Crane has decreased come from its grassland biome range. The data from the present study provide no evidence for a decrease in the Karoo and suggest a large increase in the southern Cape (fynbos biome) between the 1960's and the period 1988-1993. In addition, the present study did not detect any decrease in the southern Cape within the period 1988-1993. Nor have any other observers reported a decrease in the Karoo and fynbos biomes. The Karoo biome supports a low human density, is too arid for widespread crop farming, and has its natural vegetation largely intact (see Chapter 2). This probably explains the stable status of this population. The southern Cape region, however, like the grassland biome has a high human density and has intensive crop farming. It is unclear why this population has thrived, while the grassland population has decreased.

Siegfried (1992) estimated that 100-500 individuals occur in nature reserves in South Africa and that the Blue Crane has been recorded in at least 75 nature reserves but not necessarily as a breeding (or even regularly recorded) species. Johnson & Barnes (1986) stress the inadequacy of relying on nature reserves for the conservation of the species because too few Blue Cranes occur in too few reserves and those that do are not resident there but frequently move onto adjacent farmlands where they are vulnerable to the threats present in agricultural areas. Their comments were made with specific reference to Natal but apply equally elsewhere in South Africa.

Threats

Concomitant with the observed decreases in the grassland biome were numerous reports of poisonings of Blue Cranes. These poisonings stem from three factors (Day 1979, Holtshausen & Ledger 1985, Tarboton 1992b, Vernon *et al.* 1992, Scott 1992). They can be intentional and aimed at killing cranes which are causing agricultural damage through eating or trampling crops or foraging on supplementary feed at livestock feedlots. The ubiquitious use of agricultural habitats and incidence of crop damage caused by this species has been noted by numerous observers (Van Ee 1981, Geldenhuys 1984, Johnson & Barnes 1986, Filmer & Holtshausen 1992, Johnson 1992a, Stretton 1992, Vernon *et al.* 1992). Poisoning can be inadvertent and aimed at killing other species, such as Egyptian *Alopochen aegyptiacus* and Spurwinged *Plectropterus gambensis* Geese, Helmeted Guineafowl *Numida meleagris* or rodents, which are causing crop damage or, in the case of the large birds, for food. Alternatively, they can occur during the routine application of insecticides to crop fields. Grey Crowned Cranes and, to a lesser extent, Wattled Cranes are also subject to these poisonings.

Table 8.2 summarizes details of known poisoning incidents involving these three species in South Africa: precise details often are lacking. Most incidents of poisoning of Blue Cranes come from the southwestern Cape but this probably reflects the greater effort expended in finding and documenting such incidents in this area rather than a real concentration of incidents in this region. Why the Blue Crane apparently has decreased in the face of poisoning in the grassland biome but not in the southwestern Cape area, which also is an intensive crop farming region is obscure. In addition to the cases listed in Table 8.2, many authors mention the problem of poisoning in particular areas but without supporting details (e.g. Day 1979 - Natal, Van Ee 1981 - Cathcart in the Cape Province, Johnson & Barnes 1986 and Johnson 1992a - Natal, Vernon 1987 - Burgersdorp, Cradock, Doordrecht, Elliot, Lady Grey, Molteno and Steynsburg in the eastern Cape, Ledger 1988 - Estcourt in Natal and Philippolis in the Orange Free State, Filmer & Holtshausen 1992, Vernon *et al.* 1992 - southern Cape Province). In only five of the incidents in Table 8.2 were the poisons involved identified. In three instances monocrotophos, a seed dressing, was responsible and in the other two diazinon (trade name - 'Dazzel'), a livestock dipping agent, was used. Most cases (10/14) where the month of the incident was reported occurred during the late winter-early spring (August-October). This is the period when crops are planted or are germinating and, in the southwestern Cape, when livestock receive supplementary feed. It also is a period when cranes are still in large winter flocks (e.g. Vernon *et al.* 1992 and see Chapter 5 for the Blue Crane and Tarboton 1992a for the Grey Crowned Crane) and therefore both more vulnerable to mass mortality through poisoning and more likely to congregate in large numbers at food sources.

Commercial afforestation of the natural grassland habitats of Blue Cranes also has been identified as a major threat (Johnson 1992a). This threat is likely to intensify in the future, especially in the sour grasslands of the eastern Transvaal, Natal and eastern Cape. Other anthropogenic threats include collisions with overhead transmission lines and fences, spraying of wetlands with poisons to destroy passerine seedeaters, mortality of eggs and young from domestic dogs, drowning of young in water troughs, the taking of young into captivity as pets, entanglement of the legs in bailing twine (pers. obs), and loss of habitat due to agriculture (both crop farming and grazing practices), human settlement, mining and other human activities and disturbance (Allan 1985, Geldenhuys 1984, Tarboton, Kemp & Kemp 1987, Filmer & Holtshausen 1992, Johnson 1992a, Scott 1992, Vernon *et al.* 1992).

Table 8.2 Details of poisoning incidents involving Blue (BC), Crowned (CC) and Wattled (WC) Cranes in South Africa.

Locality	Date	Spp.	No.#	Poison	Source
Transvaal					
Belfast	1979-1988	CC	?	?	Tarboton (1992a)
Ermelo	1979-1988	CC	?	?	Tarboton (1992a)
Orange Free State					
?	1970's	BC	200+	?	Van Ee (1981)
Harrismith	mid-1980's	BC	70	?	Filmer & Holtshausen (1992)
Natal					
Dundee	1986	BC	70	?	Johnson (1992b)
Transkei					
Nxaxo	Aug. 1986	CC	30	monocr.	Bennett (1986)
E Cape					
Hofmeyer	1982	BC	400+	?	Stretton (1992)
Ugie	mid-1980's	WC	1	?	Filmer & Holtshausen (1992)
Ugie	1989	CC	1	?	Anderson (1990a)
Rhodes	Oct. 1990	CC	7	?	Urquhart (1991)
SW Cape					
?	late 1970's	BC	12	?	Day (1979)
Bredasdorp	1984	BC	?	?	Scott (1992, pers. comm.)
Napier	Sep. 1984	BC	19	diaz.	Ledger (1985)
Bredasdorp	Sep. 1985	BC	?	?	Scott (1992, pers. comm.)
Herbertsdale	Aug. 1987	BC	15	monocr.	Tyson (1987, 1988)
Riviersonderend	Aug. 1987	BC	14	monocr.	Tyson (1987, 1988)
Witsand	Sep. 1987	BC	2	?	DGA (pers obs.)
Caledon	1989	BC	?	?	Scott (1992, pers. comm.)
De Mond	1991	BC	2	?	Scott (1992, pers. comm.)
Botrivier	May 1991	BC	3	?	Scott (1992, pers. comm.)
Botrivier	May 1991	BC	14	?	Scott (1992, pers. comm.)
Rietpoel	Aug. 1991	BC	52*	diaz.	Scott (1992, pers. comm.)
Riversdale	Oct. 1991	BC	8	?	Scott (1992, pers. comm.)
Swellendam	Oct. 1992	BC	2	?	DGA (pers obs.)
Caledon	Jan. 1992	BC	1	?	Scott (1992, pers. comm.)
Caledon	Jan. 1992	BC	9	?	Scott (1992, pers. comm.)

monocr. - monocrotophos, diaz. - diazinon

- number of birds killed

* - 45 died and seven recovered after being injected with adrenalin by a veterinarian

PART TWO

THE ABUNDANCE AND MOVEMENTS OF LUDWIG'S BUSTARD, AND THE ABUNDANCE, POPULATION STRUCTURE, HABITAT SELECTION, AND CONSERVATION STATUS OF STANLEY'S BUSTARD

CHAPTER 9

THE ABUNDANCE AND MOVEMENTS OF LUDWIG'S BUSTARD *NEOTIS LUDWIGII*

CHAPTER 9

THE ABUNDANCE AND MOVEMENTS OF LUDWIG'S BUSTARD *NEOTIS LUDWIGII*

SUMMARY

An analysis of bird atlas data, road counts, an aerial census, and landowners' comments confirmed that Ludwig's Bustard Neotis ludwigii *is a winter migrant to the winter rainfall succulent Karoo biome. In addition, the species appears to migrate seasonally between the Namib and Namibian Escarpment regions. No evidence, however, could be found that the abundance of the species decreases in the summer rainfall Nama Karoo biome during the winter. There was a significant positive correlation between Ludwig's Bustard densities, as measured during road counts, and the total rainfall in the three months prior to each count, but this explained relatively little of the variation in Ludwig's Bustard densities. The total population size of the species was estimated at between 56000 and 81000 individuals.*

9.1) *Introduction*

Ludwig's Bustard *Neotis ludwigii* can be considered endemic to southern Africa, i.e. the area situated south of the Kunene and Zambezi Rivers, although its distribution extends marginally into southwestern Angola (Clancey 1986). It is listed in the South African Red Data Book as "vulnerable", largely on the basis of the putative recent retraction of its range from the eastern and northeastern limits of its distribution (Brooke 1984). Herholdt (1988), however, demonstrated that previous records from the eastern and northeastern areas within the grassland biome were based on misidentifications of Stanley's Bustards *Neotis denhami* and that Ludwig's Bustard, an inhabitant of the arid and semi-arid Namib and Karoo biomes in the west of the sub-continent, never occurred in these regions.

Apart from Herholdt's (1988) study and a brief report on measurements and diet (Earlé *et al.* 1988), Ludwig's Bustard is a poorly known species. Recent summaries of existing knowledge are found in Urban *et al.* (1986), Johnsgard (1991), and Maclean (1993). In particular, its patterns of movements remain unresolved and Urban *et al.* (1986) state it to be "resident", "a partial migrant" and "subject to local movements that are poorly known". Herholdt (1988) pointed out that the distribution of Ludwig's Bustard encompasses both the summer and winter rainfall regions of southern Africa and suggested that the species migrates between these two regions seasonally.

9.2) *Aims*

This study aims to test the hypothesis that Ludwig's Bustard migrates seasonally between the summer and winter rainfall regions. In particular, it aims to:

1) examine bird atlas data on Ludwig's Bustard from throughout its range for evidence of seasonal movements,

2) examine information from road counts made in South Africa for seasonal movements by the species,

3) report on results of a winter aerial census of Ludwig's Bustard densities in the winter rainfall region,

4) document landowner comments in the summer and winter rainfall Karoo regions on movements by the species,

5) compare the information on movements from these sources,

6) compare bustard densities, as assessed during road counts, and the patterns of rainfall recorded in the period immediately prior to the road counts, to search for a direct correlation between bustard densities and observed rainfall patterns, and

7) provide a crude estimate of the total population size of the species based on atlas data, road counts and the aerial census.

9.3) *Methods*

The analysis of the seasonal abundance of Ludwig's Bustard was made according to seventeen regions encompassing most of the range of the species (Figure 9.1). The boundaries of the seventeen regions are based on Hilton-Taylor & Le Roux (1989) for the Karoo biome in South Africa, and Brown *et al.* (1987) for the Namib and Karoo biomes in Namibia. These regions are distinguished largely on the basis of vegetation and each is situated entirely within either the summer or winter rainfall regions. The seven Karoo regions falling in the summer rainfall area are collectively termed the 'Nama Karoo' and the seven Karoo regions in the winter rainfall area are termed the 'succulent Karoo' (Rutherford & Westfall 1986). The 'southern Cape' region is the only one situated outside the Karoo and Namib biomes and falls within the intensively agriculturalized part of the fynbos biome (Moll & Bossi 1983).

Details of bird atlas reporting rates of Ludwig's Bustards were obtained from the Southern African Bird Atlas Project (SABAP, Harrison 1987, 1989, 1992). These reporting rates are a measure a relative abundance and represent the percentage of checklists on which the species was recorded relative to the total number of checklists. The geographical resolution of the atlas data was the quarter (*ca* 28 X 24 km, 15' X 15') degree grid square and the temporal resolution was the calendar month. The time periods covered by these data differed between regions (Underhill *et al.* 1991, Harrison 1992). The data from Namibia covers the period 1975-1993, from the Orange Free

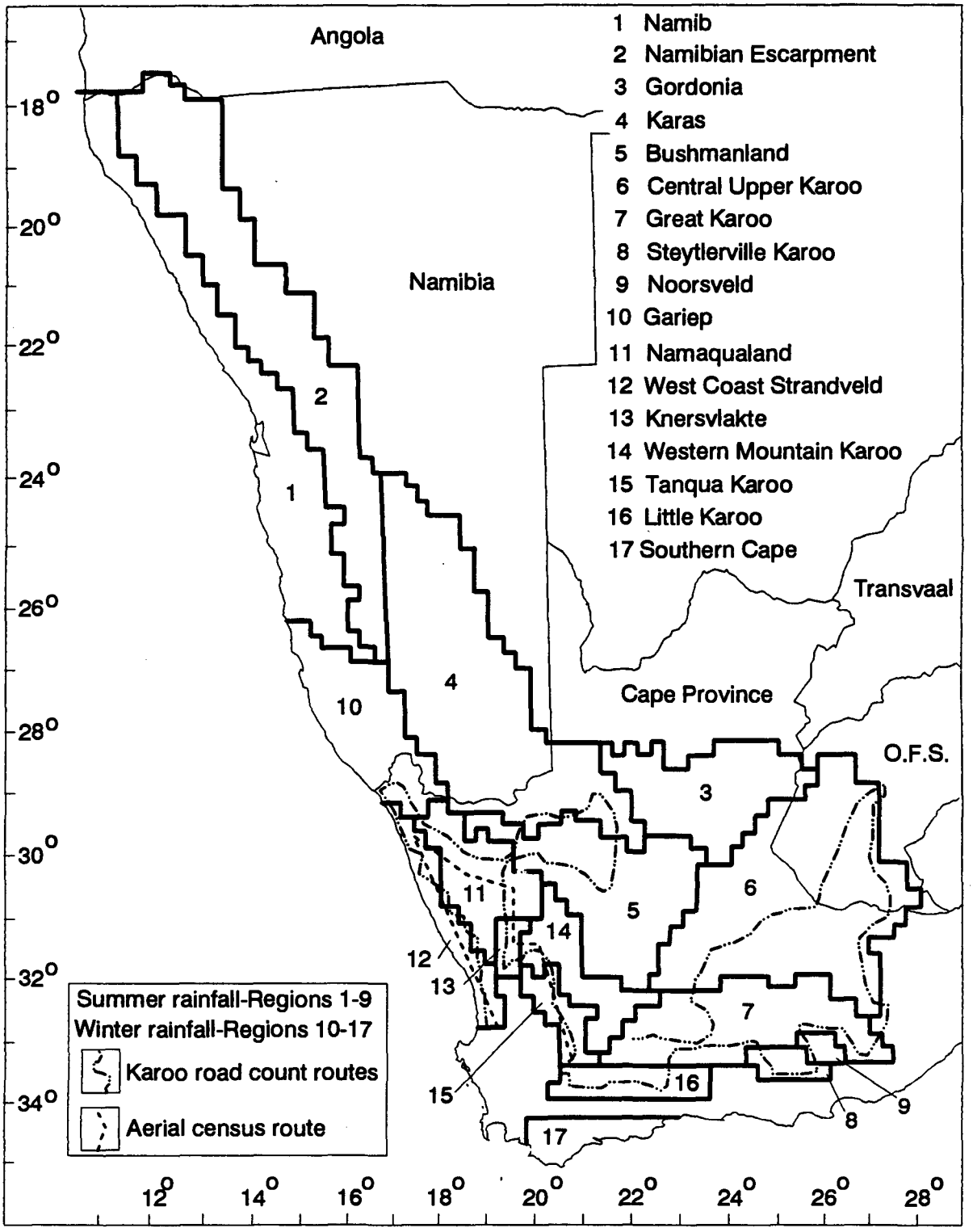

Figure 9.1 The 17 biogeographical regions within the Karoo and Namib biomes and the southern Cape used in this study. The regions within South Africa are based on Hilton-Taylor & Le Roux (1989) and those in Namibia are based on Brown *et al.* (1987). Regions one to nine lie in the summer rainfall region and regions 10 to 17 lie in the winter rainfall region. The road count routes and the route of the aerial census also are shown.

State and the southwestern Cape 1983-1991, from the eastern Cape 1985-1991, and from the northern Cape 1987-1992. In all regions the majority of data were from the period 1987-1991, except for Namibia where slightly more data came from the period prior to 1987 compared to the period 1987-1993. Reporting rates were calculated for the summer (November-April) and winter (May-October) periods in each of the 17 regions. The reporting rate for each region in each season was based on the percentage of checklists recording the species considering all checklists for the region in that season combined. The mean of the reporting rates from each square considered individually in each region for each season was not used because poor coverage of some regions resulted in unreliable reporting rates from squares with few cards. Chi-square tests were used to test the significance of seasonal differences in reporting rates in the regions.

Information on the abundance of Ludwig's Bustard also was collected during road counts made in the Karoo biome within South Africa in 1988 and 1989. Some additional data are included from road counts made in the southern Cape between 1988 and 1993. Three road count routes were established. Two were in the Karoo (Figure 9.1), one through the western and the other through the eastern Karoo. The remaining route was in the southern Cape between Caledon and Mossel Bay. The routes followed secondary (gravel) roads wherever possible. The Karoo routes were each travelled four times, twice in the winter (June-July) and twice in the summer (November-March, Appendix 9.1). The southern Cape route was done 15 times, covering all months except January and October.

The counting technique was standardized for all road counts. Two observers, including the driver, were used. The driver attempted to maintain a constant speed of 50 km/hour. Counts were stopped while travelling through built-up areas. On seeing Ludwig's Bustards, the vehicle was stopped briefly, the birds were examined through a telescope, and the locality and the number of birds was recorded. During the stop, all Ludwig's Bustards visible in the area were included in the count.

A winter aerial census of Ludwig's Bustard was made on 13 September 1989 in five of the succulent Karoo regions, i.e. Namaqualand, West Coast Strandveld, Knersvlakte, Western Mountain Karoo, and Tanqua Karoo. The route followed was Stellenbosch - Vredendal - Kleinsee - Springbok - Vanrhynsdorp - Nieuwoudtville - Karoopoort (Figure 9.1). A four-seater high-wing aeroplane was flown at an altitude of 150 m above ground level. Two observers were used, one on each side of the aeroplane, in addition to the navigator and pilot. All Ludwig's Bustards recorded within a 500 m strip on each side of the aeroplane were counted, resulting in an effective strip width of 1000 m. Streamers were attached to the wing struts to delineate the strip widths on each side of the aeroplane (Caughley 1980). The total distance flown in the succulent Karoo was 790 km. Ludwig's Bustards were seen as they flew off when the aeroplane

approached and no birds were seen on the ground. Ludwig's Bustard is cryptically coloured and it is unlikely that they would be visible from an aeroplane if they did not fly. In flight, however, the species shows conspicuous white markings in the wings and it is unlikely that any birds flushed within the effective strip width were overlooked, unless they flew after the aeroplane had passed over them. It was assumed that all birds within the effective strip were flushed and counted. A flock of 40 Ludwig's Bustards seen during the flight in an agricultural field adjacent to the town of Nieuwoudtville was excluded from the analysis, as the localized area of intensive crop farming around this town is not representative of the Western Mountain Karoo region.

Seventy-seven landowners in the Karoo regions of South Africa, 57 in the Nama Karoo and 20 in the succulent Karoo, were questioned about the seasonal presence of Ludwig's Bustards on their farms. These landowners either responded to a postal questionnaire or were interviewed. They were asked whether they noted the species more frequently in the summer or in the winter, or whether the species was recorded at similar frequencies throughout the year.

Information on monthly rainfall during the period February 1988 and July 1989 in each of the 13 succulent and Nama Karoo regions where road counts were made was obtained from the Department of Water Affairs. Data from between one and eight rainfall stations in each region were used in this analysis.

9.4) *Results*

Bird atlas data

The Namib and Namibian escarpment regions showed a complementary change in reporting rates between the summer (November-April) and the winter (May-October; Figure 9.2, Table 9.1). In the Namib, reporting rates were significantly higher in the winter, while in the Namibian escarpment they were significantly higher in the summer. This suggests an east-west seasonal movement between these two regions.

In the Nama Karoo there was no clear pattern of seasonal changes in reporting rates between the summer and the winter. In four regions, reporting rates were higher in summer and in three regions reporting rates were higher in winter. In only two regions were the seasonal differences in reporting rates significant: in the Gordonia region reporting rates were significantly higher in the summer, while in Bushmanland reporting rates were significantly higher in winter. Pooling the data from all the Nama Karoo regions revealed no significant difference in reporting rates between the two seasons.

The succulent Karoo showed an obvious and consistent increase in reporting rates in the winter (Figure 9.2). Reporting rates were higher in all regions in the winter and these differences were all significant except in the Little Karoo. Data from the southern

Table 9.1 Atlas reporting rates of Ludwig's Bustard in various summer and winter rainfall regions of southern Africa during the summer (November-April) and winter (May-October) periods.

Region	Reporting rate Summer	Winter	χ^2=	*P* value	Number of checklists Summer	Winter
Summer rainfall						
1 Namib	8,9	13,8	25,8	$P<0,0001$	2040	2289
2 Namibian Escarpment	13,6	9,6	11,2	$P<0,001$	1372	1495
Karoo						
3 Gordonia	3,6	0,6	22,2	$P<0,0001$	894	1029
4 Karas	7,1	5,9	1,3	n.s.	1036	1289
5 Bushmanland	18,8	25,7	5,2	$P<0,05$	336	448
6 Central Upper Karoo	15,8	15,4	0,1	n.s.	2002	2071
7 Great Karoo	26,6	27,3	0,2	n.s.	1540	1589
8 Steytlerville Karoo	26,6	32,7	1,8	n.s.	203	196
9 Noorsveld	12,1	12,2	5,6	n.s.	66	98
Summer rainfall Karoo total	15,7	15,3	0,5	n.s.	6077	6720
Winter rainfall						
Karoo						
10 Gariep	6,4	12,9	11,7	$P<0,001$	484	498
11 Namaqualand	6,7	23,2	25,9	$P<0,0001$	209	396
12 West Coast Strandveld	2,7	9,7	19,3	$P<0,0001$	445	505
13 Knersvlakte	4,1	25,5	10,1	$P<0,005$	49	106
14 Western Mountain Karoo	4,8	19,5	26,0	$P<0,0001$	231	385
15 Tanqua Karoo	3,7	19,6	14,4	$P<0,0001$	109	158
16 Little Karoo	0,8	1,0	0,1	n.s.	394	514
Winter rainfall Karoo total	4,0	13,3	113,8	$P<0,0001$	1921	2562
17 Southern Cape	0,0	0,1	2,1	n.s.	1468	1420

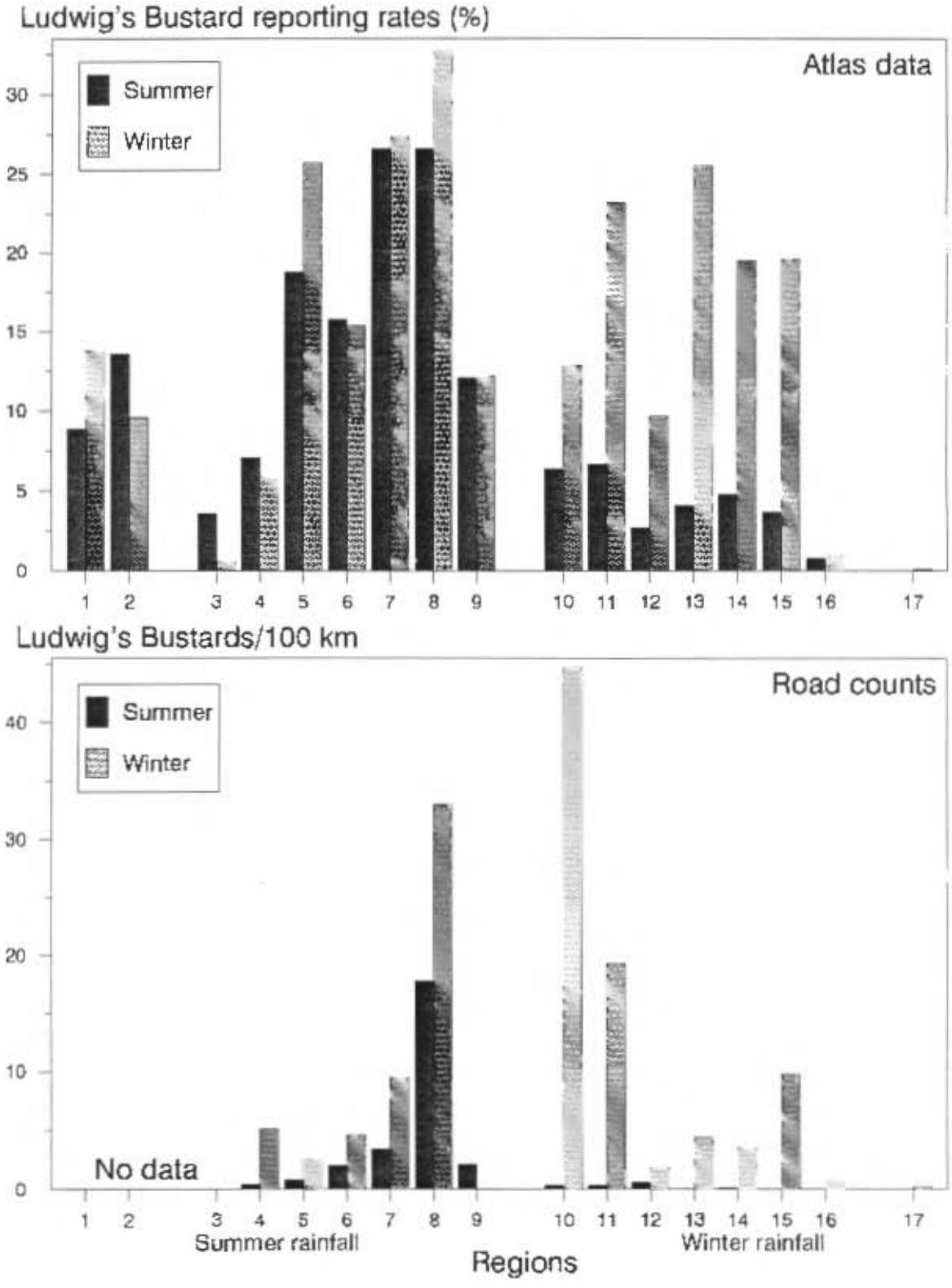

Figure 9.2 Atlas reporting rates and road counts of Ludwig's Bustards in the 17 regions within the range of the species, presented separately for the summer (November-April) and winter (May-October) periods. The name of each region corresponding with each number can be found in Figure 1

Cape were few, due to the scarcity of the species in this region, and showed a slightly, but not significantly, higher reporting rate in the winter (Table 9.1).

Road counts

In the Nama Karoo more Ludwig's Bustards were counted during road counts in the winter (May-October) than in the summer (November-April), except in the Noorsveld where the sample size was small, but this difference was not significant (U=49,0, P>0,05, Mann-Whitney U-test; Figure 9.2, Table 9.2, Appendix 9.1). Significantly more Ludwig's Bustards were counted in the winter than in the summer in all of the succulent Karoo regions (U=25,5, P<0,05). Ludwig's Bustards were recorded in the southern Cape region on only five occasions, all in the winter.

Atlas reporting rates and road count data (Figure 9.3) were significantly and positively correlated (r_s=0,762, P<0,01, one-tailed test, Spearman Rank Correlation Coefficient). The nature of the relationship was logarithmic.

Aerial census

Ludwig's Bustards were recorded during the aerial census in all five of the succulent Karoo regions covered (Table 9.3). There was a significant positive correlation (r_s=1,000, P<0.05, one-tailed test, Spearman Rank Correlation Coefficient) between the density of birds found during the September 1989 aerial census and the number of birds counted during road counts in the same winter (June 1989) in the same five regions (Figure 9.4), although the sample size was small.

Landowners' comments

The majority (71,9%) of farmers in the Nama Karoo reported that Ludwig's Bustard was recorded at similar frequencies throughout the year, 17,6% reported that the birds were more common in the summer, and the remainder (10,5%) reported that Ludwig's Bustards were more common in the winter (Table 9.4). The majority (90,0%) of farmers in the succulent Karoo reported that the species was recorded more frequently during the winter and the remainder reported that the species was more common during the summer. The differences in landowners' comments between the two regions was highly significant (χ^2=45,1, P<0,001, d.f.=2), with significantly more farmers in the Nama Karoo reporting the species as occurring at constant frequency throughout the year and significantly more farmers in the succulent Karoo reporting the species to be a winter visitor.

Table 9.2 The number of Ludwig's Bustard individuals counted per 100 km during road counts in various regions of the Nama Karoo (summer rainfall), and the succulent Karoo and southern Cape (winter rainfall), in summer (November-April) and winter (May-October).

Region	Summer	Winter
Summer rainfall		
4 Karas	0,4	5,1
5 Bushmanland	0,8	2,5
6 Central Upper Karoo	2,0	4,6
7 Great Karoo	3,4	9,5
8 Steytlerville Karoo	17,8	33,0
9 Noorsveld	2,1	0,0
Summer rainfall Karoo total	3,0	7,1
Winter rainfall		
10 Gariep	0,3	44,7
11 Namaqualand	0,3	19,3
12 West Coast Strandveld	0,6	1,8
13 Knersvlakte	0,0	4,4
14 Western Mountain Karoo	0,1	3,5
15 Tanqua Karoo	0,0	9,8
16 Little Karoo	0,0	0,6
Winter rainfall Karoo total	0,3	13,6
17 Southern Cape	0,0	0,2

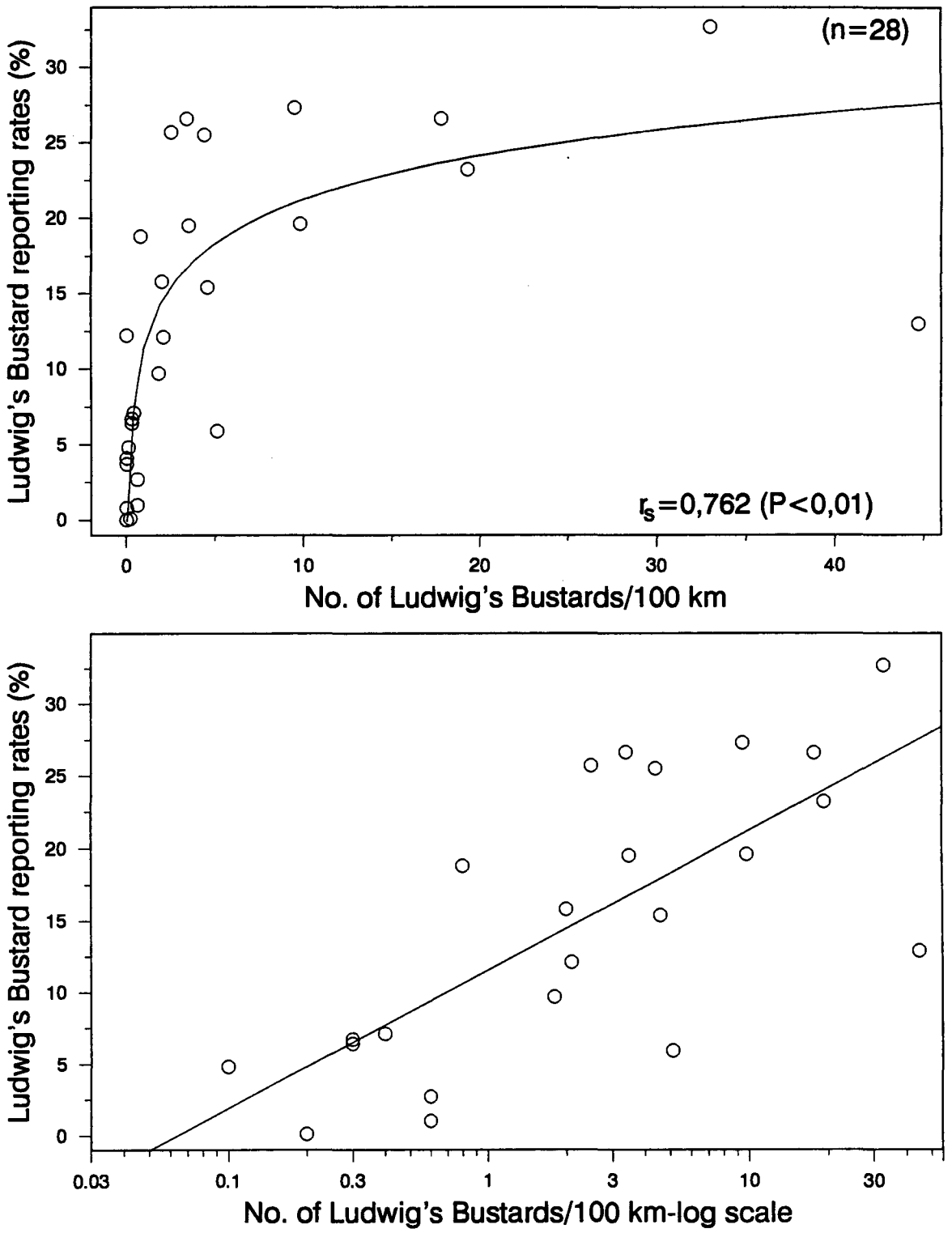

Figure 9.3 The relationship between atlas reporting rates and road counts of Ludwig's Bustards. The lower graph shows the same data as the upper graph but the x-axis has been logged.

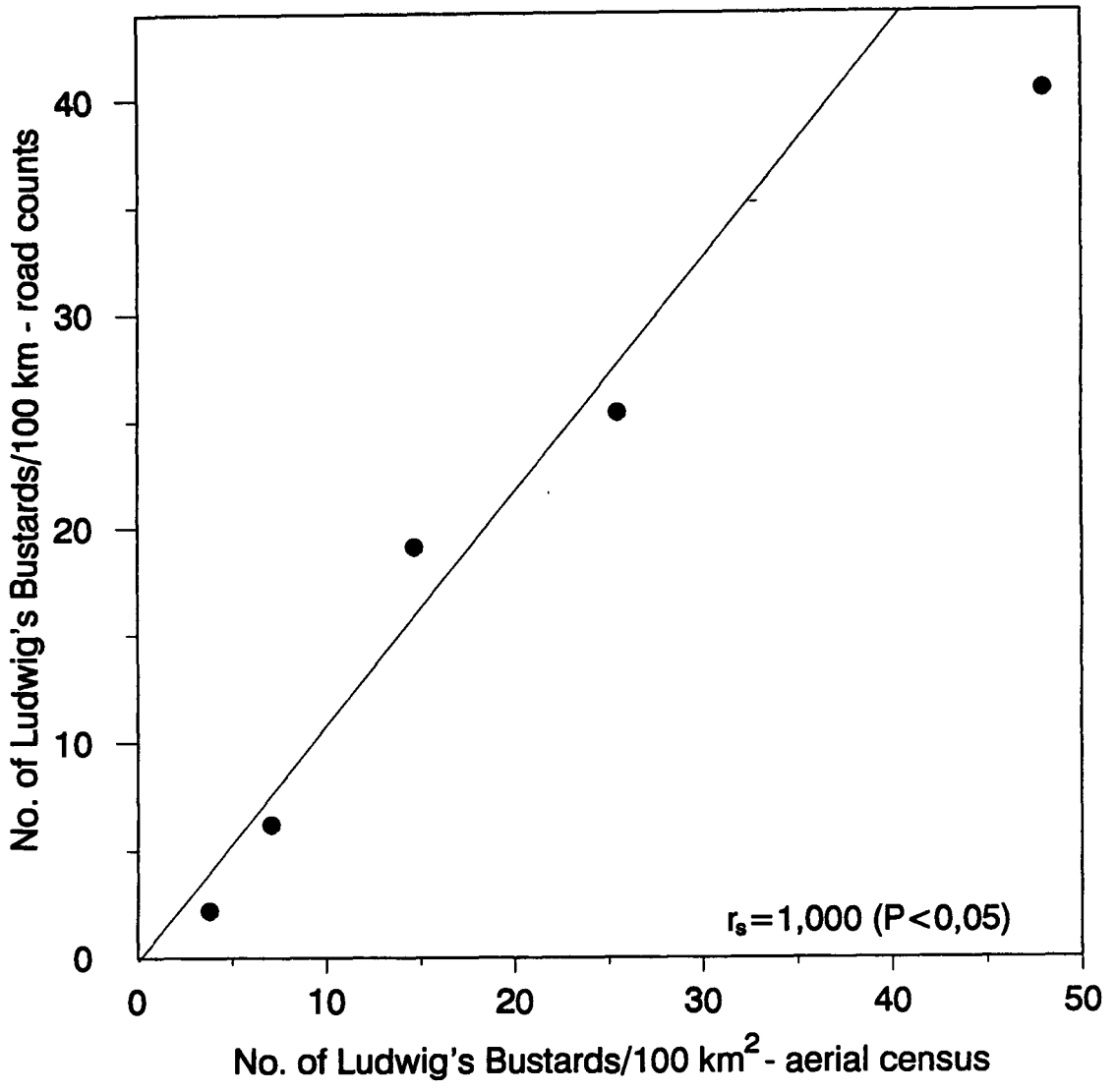

Figure 9.4 The relationship between the density of Ludwig's Bustards found during the aerial census made through five succulent Karoo regions (Namaqualand, West Coast Strandveld, Knersvlakte, Western Mountain Karoo, Tanqua Karoo) in September 1989 and the number of Ludwig's Bustards counted per 100 km of road counts made in the same five regions during the same winter (June 1989). The line was fitted using the regression equation y=1,0874x.

Table 9.3 Numbers of Ludwig's Bustards recorded during an aerial census in five succulent Karoo regions in the winter of 1989.

Region	Area covered	No. of Ludwig's Bustards	Density of Ludwig's Bustards inds/100 km^2
11 Namaqualand	165 km^2	42	25,5
12 West Coast Strandveld	320 km^2	12	3,8
13 Knersvlakte	85 km^2	6	7,1
14 Western Mountain Karoo	50 km^2	24	48,0
15 Tanqua Karoo	170 km^2	25	14,7

Table 9.4 Landowners' comments on the migratory status of Ludwig's Bustards on farms in the summer and winter rainfall Karoo regions.

	Summer rainfall region		**Winter rainfall region**	
Status	no.	%	no.	%
"More frequent in summer"	10	17,6%	2	10,0%
"More frequent in winter"	6	10,5%	18	90,0%
"Same frequency throughout the year"	41	71,9%	0	0%
Totals	57		20	

Comparison of road counts and actual rainfall

Ludwig's Bustard densities, as measured during road counts, and the total rainfall during the three months prior to each count through each region in the succulent and Nama Karoo biomes were significantly positively correlated (Figure 9.5). In Figure 9.5, two outlying points have been excluded. An example of this specific response to a local rainfall event was found in six of the succulent Karoo regions, i.e. Gariep, West Coast Strandveld, Knersvlakte, Tanqua Karoo, Namaqualand, and Western Mountain Karoo, particularly in the first four of these regions. In the winter of 1988, rainfall in these four regions was below average and bustard densities were lower than those found in the winter of 1989 (Fig. 9.6), where a high rainfall event occurred in April, two to three months prior to the road counts through these regions. The effect was particularly marked in the Gariep where 33 mm of rainfall was recorded in April 1989, which is 690% of the average for that month. During the June 1989 road count through this region the highest density of Ludwig's Bustards observed during this study was recorded (87,6 birds/100 km). Ludwig's Bustard densities in these six regions were all higher in the winter of 1989 than in the winter of 1988 ($T=0$, $P<0,05$, Wilcoxon Test for Matched Pairs).

Rainfall in the Nama Karoo (Figure 9.7) tended to be above average during the study period. In particular, the first winter road counts through these regions were made after extremely high late summer rainfall. Consistently low bustard densities were found in the Little Karoo and Noorsveld regions, irrespective of rainfall patterns (Figures 9.6 and 9.7).

Total population estimate

The atlas reporting rate, road count and aerial census data were used to estimate the total population size of Ludwig's Bustard in each of the 16 regions covered by the Karoo, Namib and Namibian Escarpment (Table 9.5). For the five regions covered in the aerial census, the estimates were derived from extrapolations of the measured densities over the total area of each region. For the eight regions for which only road count data were available, the densities were estimated using the data in Figure 9.4 (regression analysis), and then extrapolated over the total area of each region. For the three regions for which only atlas reporting rate data were available, the road count abundances were estimated using the data shown in Figure 9.3, the estimated densities were then calculated using the data shown in Figure 9.4, and these were extrapolated over the total area of each region. The estimates were based on the winter abundance data, as this was when the aerial count was made and because more birds were recorded during road counts in winter than in summer (Table 9.2).

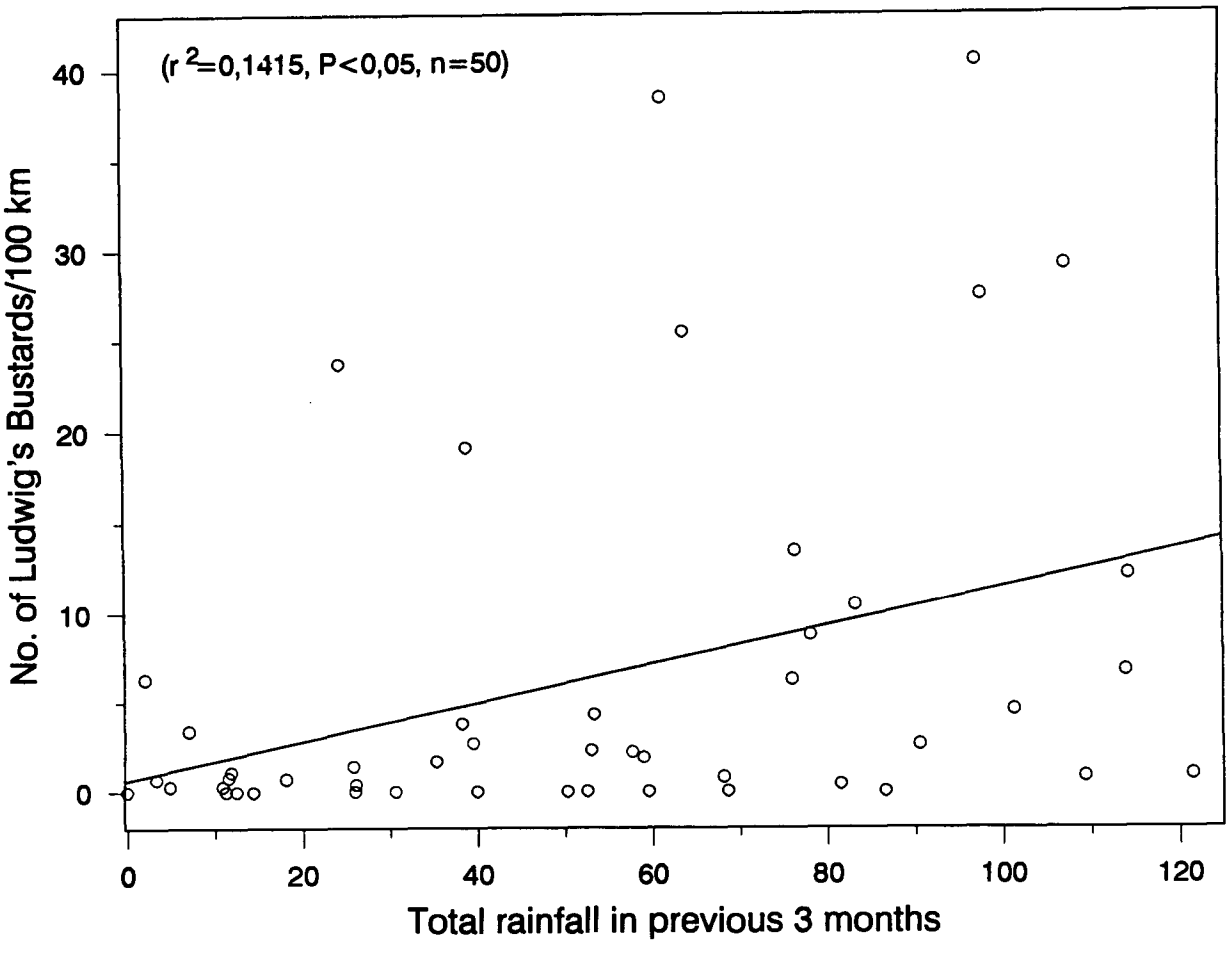

Figure 9.5 The relationship between the number of Ludwig's Bustards counted per 100 km during road counts and the total amount of rainfall in the three months prior to each of the four counts in each of the 13 succulent and Nama Karoo regions in which road counts were made.

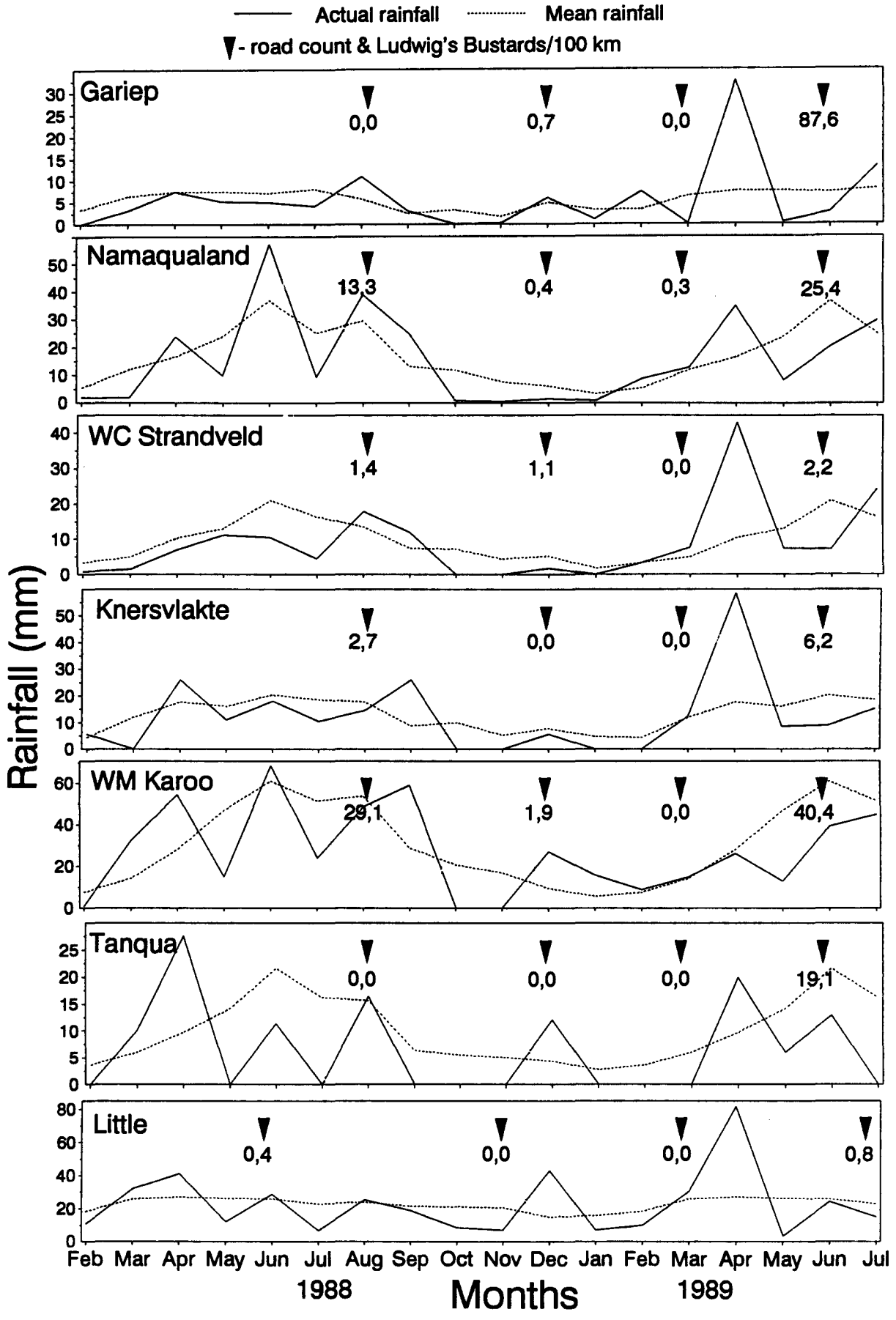

Figure 9.6 Monthly rainfall and the long-term average monthly rainfall for each of the seven succulent Karoo regions during the period when road counts were made and the number of Ludwig's Bustards counted per 100 km during each count.

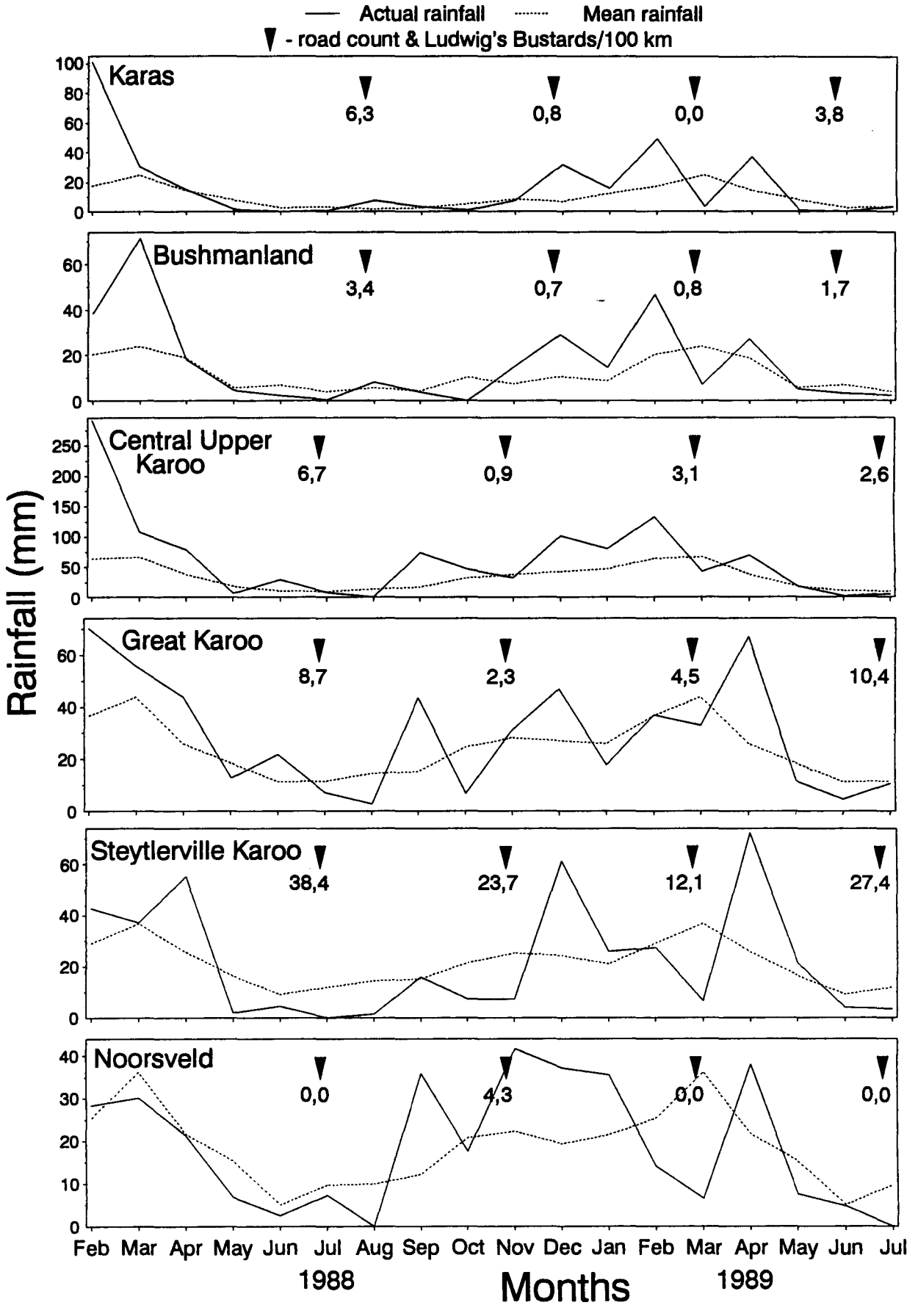

Figure 9.7 Monthly rainfall and the long-term average monthly rainfall for each of the six Nama Karoo regions during the period when road counts were made and the number of Ludwig's Bustards counted per 100 km during each count.

Table 9.5 Summary of abundance data used in deriving a total population estimate of Ludwig's Bustard in the Namib, Namibian Escarpment, and the Karoo during the winter of 1989.

Region		Winter rep. rate	Winter road counts (inds/ 100 km)	Aerial count (inds/ 100 km^2)	Area (km^2)	**Estimated no. of Ludwig's Bustards**
1	Namib	13,8%	2,4[1]	2,6[2]	112000	**2912**
2	Namibian Escarpment	9,6%	1,4[1]	1,5[2]	124600	**1869**
3	Gordonia	0,6%	0,1[1]	0,1[2]	54600	**55**
4	Karas		5,1	5,6[2]	142100	**7958**
5	Bushmanland		2,5	2,7[2]	72100	**1947**
6	Central Upper Karoo		4,6	5,0[2]	135800	**6790**
7	Great Karoo		9,5	10,3[2]	64400	**6633**
8	Steytlerville Karoo		33,0	35,9[2]	7700	**2764**
9	Noorsveld		1,1[3]	1,2[2]	4200	**50**
10	Gariep		44,7	48,6[2]	52500	**25515**
11	Namaqualand			25,5	35000	**8925**
12	West Coast Strandveld			3,8	16800	**638**
13	Knersvlakte			7,1	6300	**447**
14	Western Mountain Karoo			48,0	26600	**12768**
15	Tanqua Karoo			14,7	13300	**1955**
16	Little Karoo		0,6	0,7[2]	14000	**98**
Totals					**882000**	**81324**

[1] - estimated from Fig. 3 ($y=0,0386\log[x+1]$)
[2] - estimated from Fig. 4 ($y=1,0874x$)
[3] - summer counts; no birds seen during winter counts

The total population estimate for Ludwig's Bustard in the winter in the Karoo, Namib and Namibian Escarpment was 81300 birds (Table 9.5). The Namib and Namibian escarpment population was estimated at about 4800 birds, the Nama Karoo population at 26200 birds, and the succulent Karoo population at 50300 birds. No meaningful confidence limits can be applied to these estimates.

9.5) *Discussion*

The information from bird atlas data, road counts and landowners' comments are consistent with one another and confirm the hypothesis that Ludwig's Bustard migrates into the succulent Karoo during the winter. In addition, the atlas data suggest a previously unsuspected migration between the Namib and Namibian escarpment regions that mirrors the movement into the succulent Karoo during the winter. An unexpected result, however, was that no evidence could be found in any of the data for a significant reduction in numbers of Ludwig's Bustards in the Nama Karoo during winter concomitant with the marked influx of birds to the succulent Karoo at this time. Indeed, consistently more Ludwig's Bustards were counted in the winter in the Nama Karoo during road counts than in the summer, although this difference was not significant. Several factors may be responsible for this anomaly and these are discussed below.

1) The species is only a partial migrant, with some individuals being present throughout its range at all times of the year.

2) The Nama Karoo covers a much larger area (480900 km^2) than the succulent Karoo (164500 km^2). The proportion of the population moving from the Nama Karoo to the succulent Karoo in the winter may be relatively small. The total population estimates in each region, however, do not support this hypothesis. It was estimated that in the winter of 1989 there were about 50300 Ludwig's Bustards in the succulent Karoo and about 26200 in the Nama Karoo. The estimate for the succulent Karoo, however, is heavily influenced by the high estimate for the Gariep region (25515 birds). The estimate for the Gariep is based on a high road count of bustards in this region made after a period of unusually high rainfall. Ludwig's Bustard densities in the Gariep probably are much lower during periods of normal rainfall. In addition, much of the Gariep is mountainous and therefore unsuitable for the species but the road count route through the region was through a relatively flat area, which probably was not representative of the region as a whole resulting in an overestimate of abundance.

3) The rainfall prior to and during the period when road counts were made in the Nama Karoo was above average and fewer bustards may have left this biome in the

winter than would normally be the case. The above average rainfall in the Nama Karoo during the study period may be at least partly responsible for the anomolous road count results in the Nama Karoo, where higher bustard densities were recorded in the winter than in the summer. The comparison of bustard road counts and the total rainfall in the three months prior to each count in each region showed a significant positive correlation between bustard density and recent rainfall. This correlation, however, explained relatively little of the variation in the densities of Ludwig's Bustards. Clearly, other factors in addition to rainfall also were responsible for variation in bustard densities. For example, in the Little Karoo and Noorsveld, bustard densities were consistently low irrespective of rainfall patterns. This suggests that these two vegetation types never offer suitable habitat for the species. Indeed, these two regions are considered by some authors to fall within the woodland biome, rather than the Karoo biome (Huntley 1984, Rutherford & Westfall 1986). In the Steytlerville Karoo, bustard densities were consistently high, again apparently irrespective of rainfall patterns. By contrast, local rainfall events clearly elevated bustard densities in the Gariep, West Coast Strandveld, Knersvlakte, and Tanqua Karoo regions. The use of total rainfall in this comparison of bustard densities and rainfall was not entirely satisfactory as a relatively low amount of rainfall in a highly arid region, e.g. the Gariep, may attract high densities of bustards, while the same amount of rainfall in a region of higher mean rainfall would not constitute above average rainfall and therefore would not result in conditions that would attract large numbers of bustards.

4) Evidence from road counts of several small bustards (*Eupodotis* spp.) suggests that bustards are more conspicuous during the winter. Karoo *Eupodotis vigorsii*, Blue *E. caerulescens*, Black *E. afra*, and Whitewinged Black *E. afraoides* Korhaans were all recorded at higher frequencies in both the succulent and Nama Karoo biomes during road counts in the winter than in the summer (Figure 9.8). These species all are believed to be sedentary (Maclean 1993) and therefore their densities presumably were the same during both seasons. This apparent increase in conspicuousness in Ludwig's Bustard and *Eupodotis* spp. may be related to increased activity during the winter and possibly to seasonal changes in vegetation height and density. In the Nama Karoo, where grasses (Poaceae) are a major component of the vegetation, changes in grass height and density may be particularly important in influencing the conspicuousness of bustards. In addition, in the summer rainfall area breeding occurs during the summer months and breeding females are likely to become less conspicuous at this time.

The strong corroboration between the bird atlas data, road counts, the aerial census, and landowners' comments in elucidating the abundance of Ludwig's Bustards increases

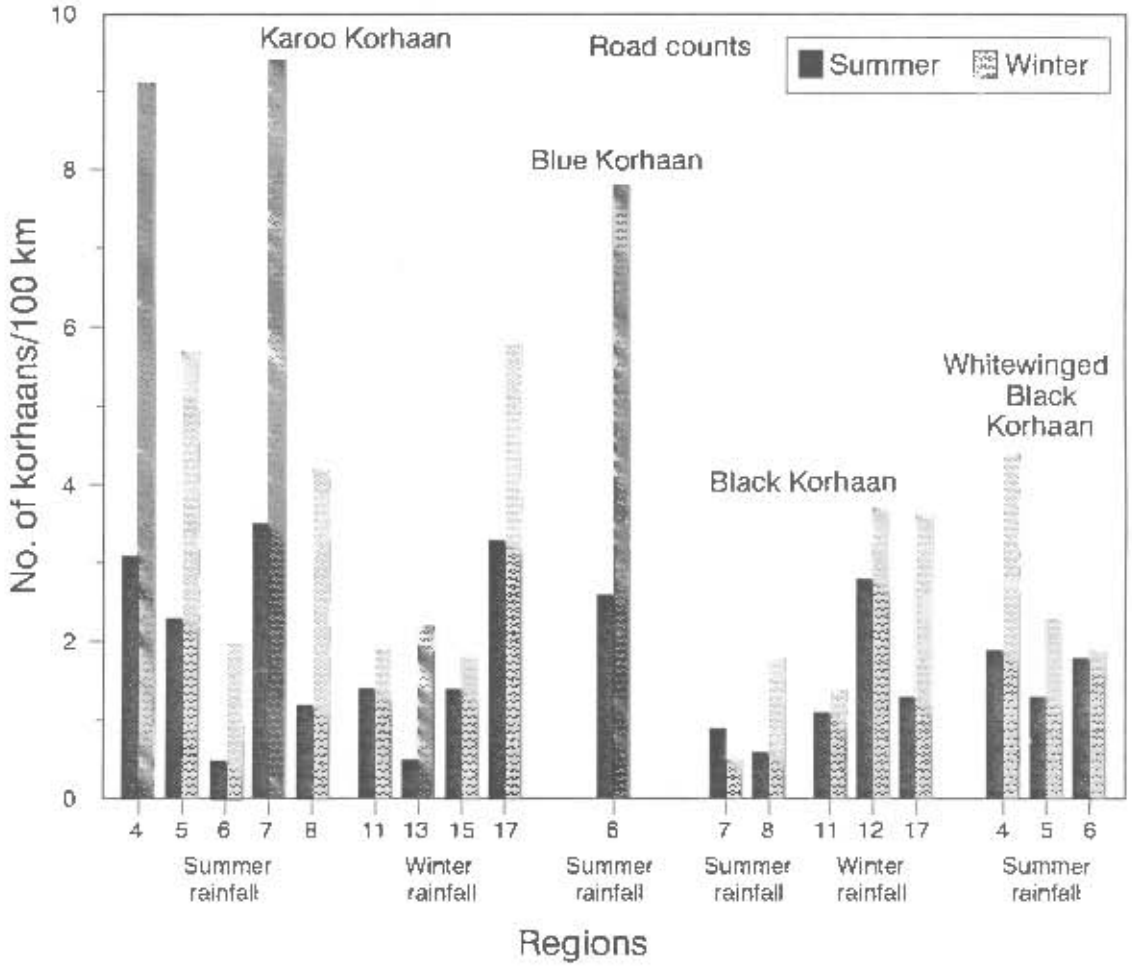

Figure 9.8 The number of Karoo, Blue, Black and Whitewinged Black Korhaans seen per 100 km during road counts in various summer and winter rainfall regions of South Africa, presented separately for the summer (November-April) and winter (May-October) periods. The name of each region corresponding with each number can be found in Figure 1.

the confidence that can be placed in the reliability of the results of this study. In particular, this study is the first to provide a statistically significant confirmation that atlas reporting rates are positively correlated with some other independent measure of abundance (road counts). Seasonal changes in the group sizes of Blue Cranes *Anthropoides paradiseus* confounded analyses of movements based on atlas data: reporting rates were lower in the winter, despite an actual increase in density, as measured during road counts, due to the localization of the cranes into winter flocks Chapter 4). In this study of Ludwig's Bustards, however, seasonal changes in reporting rates were consistent with seasonal changes in the number of bustards counted during road counts. Although there was a significant seasonal change in the mean group sizes of Ludwig's Bustards observed during road counts between the summer (2,22, S.D.=1,69, n=82) and winter (3,51, S.D.=5,01, n=124; F=2,06, P<0,01, F-test) this difference was far smaller than that found in the Blue Crane and apparently did not confound the association between the two measures of abundance. It might, however, have had some slight but apparently insignificant effect on the reporting rates between the summer and winter in the various regions, which would have tended to inflate the summer reporting rates relative to the winter reporting rates.

Appendix 9.1 The dates and number of kilometres travelled on the road counts through the various regions of the succulent and Nama Karoo biomes and the southern Cape, and the number of Ludwig's Bustard individuals and groups counted during each road count.

Region	Date	No. km	No. inds	No. grps
KAROO				
Succulent Karoo				
Gariep	Aug. 1988	139	0	0
	Dec. 1988	145	1	1
	Mar. 1989	146	0	0
	Jun. 1989	145	127	14
	Total	**575**	**128**	**15**
Namaqualand	Aug. 1988	730	98	30
	Dec. 1988	747	3	2
	Mar. 1988	747	2	1
	Jun. 1988	752	191	51
	Total	**2976**	**294**	**84**
West C Strandveld	Aug. 1988	355	5	3
	Dec. 1988	361	4	4
	Mar. 1989	360	0	0
	Jun .1989	357	8	3
	Total	**1433**	**17**	**10**
Knersvlakte	Aug. 1988	188	5	2
	Dec. 1988	189	0	0
	Mar. 1989	193	0	0
	Jun. 1989	178	11	3
	Total	**748**	**16**	**5**
Western Mountain	Aug. 1988	55	16	3
	Dec. 1988	54	1	1
	Mar. 1989	57	0	0
	Jun. 1989	57	23	3
	Total	**223**	**40**	**7**
Tanqua	Aug. 1988	188	0	0
	Dec. 1988	163	0	0
	Mar. 1989	190	0	0
	Jun. 1989	199	38	13
	Total	**740**	**38**	**13**
Little	Jun. 1988	262	1	1
	Nov. 1988	258	0	0
	Mar. 1989	264	0	0
	Jul. 1989	259	2	1
	Total	**1043**	**3**	**2**
Succ. Karoo total		*7738*	*536*	*136*
Nama Karoo				
Karas	Aug. 1988	240	15	7
	Dec. 1988	237	2	1
	Mar. 1989	243	0	0
	Jun. 1989	235	9	4
	Total	**955**	**26**	**12**

Appendix 9.1 (cont.)

Region	Date	No. km	No. inds	No. grps
Bushmanland	Aug. 1988	701	24	8
	Dec. 1988	718	5	4
	Mar. 1989	733	6	3
	Jun. 1989	716	12	5
	Total	**2868**	**47**	**20**
Central Upper Karoo	Jul. 1988	1172	78	16
	Nov. 1988	1132	10	8
	Mar. 1989	1146	36	15
	Jul. 1989	1158	30	6
	Total	**4608**	**154**	**45**
Great Karoo	Jul. 1988	658	57	25
	Nov. 1988	647	15	7
	Mar. 1989	651	29	14
	Jul. 1989	643	67	22
	Total	**2599**	**168**	**68**
Steytlerville	Jul. 1988	219	84	19
	Nov. 1988	211	50	18
	Mar. 1989	215	26	10
	Jul. 1989	215	59	12
	Total	**857**	**219**	**59**
Noorsveld	Jul. 1988	75	0	0
	Nov. 1988	70	3	2
	Mar. 1989	76	0	0
	Jul. 1989	74	0	0
	Total	**295**	**3**	**2**
Nama Karoo total		*12182*	*617*	*206*
Succ. & Nama Karoo total	**19920**	**1153**	**342**	
SOUTHWESTERN CAPE				
Southern Cape	Sep. 1988	483	0	0
	Jun. 1989	509	0	0
	Jul. 1989	563	0	0
	Mar. 1990	576	0	0
	Jul. 1990	564	0	0
	Nov. 1990	588	0	0
	Feb. 1991	583	0	0
	May 1991	605	0	0
	Jul. 1991	596	5	3
	Nov. 1991	584	0	0
	Mar. 1992	581	0	0
	Jun. 1992	580	0	0
	Aug. 1992	591	2	2
	Dec. 1992	593	0	0
	Apr. 1993	588	0	0
	Total	**8584**	**7**	**5**
Southern Cape total		*8584*	*7*	*5*
KAROO & STHN CAPE TOTAL		**28504**	**1160**	**347**

CHAPTER 10

THE ABUNDANCE, POPULATION STRUCTURE, HABITAT SELECTION AND CONSERVATION STATUS OF STANLEY'S BUSTARD *NEOTIS DENHAMI STANLEYI* IN THE SOUTHERN CAPE PROVINCE, SOUTH AFRICA

CHAPTER 10

THE ABUNDANCE, POPULATION STRUCTURE, HABITAT SELECTION AND CONSERVATION STATUS OF STANLEY'S BUSTARD *NEOTIS DENHAMI STANLEYI* IN THE SOUTHERN CAPE PROVINCE, SOUTH AFRICA

SUMMARY

In the southern Cape Province, Stanley's Bustards Neotis denhami stanleyi *were recorded more frequently during road counts in winter than in summer. The estimated winter population in the region was 956 birds (464-1447). The species was not recorded during road counts in the Swartland and succulent Karoo, and was rare in the Nama Karoo. Stanley's Bustards bred in the southern Cape between August and January, mainly during September and October. The sex ratio, as measured during the non-breeding season, was biased towards females (1,00 female:0,69 males). Group sizes were smaller in the non-breeding season than in the breeding season. Both males and females were more likely to be seen solitarily in the summer than in the winter. Males and females tended to form single sex groups and sightings of a single male and female together were extremely rare. Cultivated pastures were a favoured habitat during the winter but were used in proportion to their availability during the summer. Natural vegetation was favoured in the breeding season but avoided in the non-breeding season. Harvested cereal crop fields were favoured when they were available, but ploughed fields and fields with growing cereal crops were avoided throughout the year.*

10.1) *Introduction*

The subspecies of Denham's Bustard *Neotis denhami*, a widespread Afro-tropical species, found in South African is Stanley's Bustard *N. d. stanleyi*. This race is virtually endemic to South Africa and is classified as "vulnerable" in the South African Red Data Book (Brooke 1984). Johnsgard (1991) recently reviewed current knowledge about the various races of Denham's Bustard. Stanley's Bustard is poorly known and the only detailed studies are of its breeding behaviour (Tarboton 1989) and distribution (Herholdt 1988). Its range long was thought to encompass the Karoo, fynbos and grassland biomes of South Africa (e.g. Clancey 1964, Urban *et al.* 1986). Herholdt (1988), however, showed that most records of Stanley's Bustards from the Karoo were mis-identifications of Ludwig's Bustards *N. luwigii*, and that the habitat of Stanley's Bustard was sour grassland and coastal fynbos. It occurs in karroid dwarf shrublands only as a vagrant and in those parts of the Karoo that are directly adjacent to the sour grassland and fynbos biomes.

The southern Cape Province falls within the fynbos biome, but much of the natural vegetation (fynbos, renosterveld and strandveld) has been removed and replaced by agricultural crop fields (Moll & Bossi 1983), mainly cereal crops, and cultivated pastures for smallstock, mainly Merino sheep. Stanley's Bustard has been described as localized and uncommon in this area (Hockey *et al.* 1989), where the species also breeds (e.g. Uys 1963).

10.2) *Aims*

The aims of this study were to examine the abundance, group sizes, sex ratios, and habitat selectivity of Stanley's Bustards in the southern Cape, including an analysis of seasonal variation in these attributes of the species.

10.3) *Study area and methods*

Road counts were made in the southern Cape coastal plain between Botrivier and Mossel Bay during the period September 1988 and April 1993. Figure 10.1 shows the boundaries of the southern Cape region, the areas comprising natural vegetation and cultivated regions (after Moll & Bossi 1983), and the road count route. The route followed secondary (gravel) roads wherever possible and was travelled 15 times, covering all months except January and October. Table 10.1 lists the dates and the number of kilometres travelled during each count. The slight differences in distances between counts are due to minor logistical factors inherent to the large distances traversed. Brief mention also is made of the number of Stanley's Bustards recorded during the road counts in the Swartland (southwestern Cape) and the Karoo (see Chapters 3 and 9).

The counting technique was standardized for all of the counts. Two observers, including the driver, were used. The driver attempted to maintain a constant speed of 50 km/hour. Counts were stopped while travelling through built-up areas. On seeing a group of Stanley's Bustards, the vehicle was stopped briefly, the group was examined through a telescope, and details of the time of day, locality, group size, sexes, activity, and habitat were recorded. During the stop, all bustards visible in the area were considered as part of the same group even if they were relatively widely dispersed. The same details were recorded for bustards seen at other times in the area so that these additional data could be incorporated in the study where relevant. The group sizes of 342 Stanley's Bustard groups were measured in this way. Data on the sizes of an additional 420 groups were gathered from other observers who responded to an appeal through the media for information on the species in the southern Cape, and from records published in the Cape Bird Club's newsletter *Promerops*, numbers 1-210. In the same

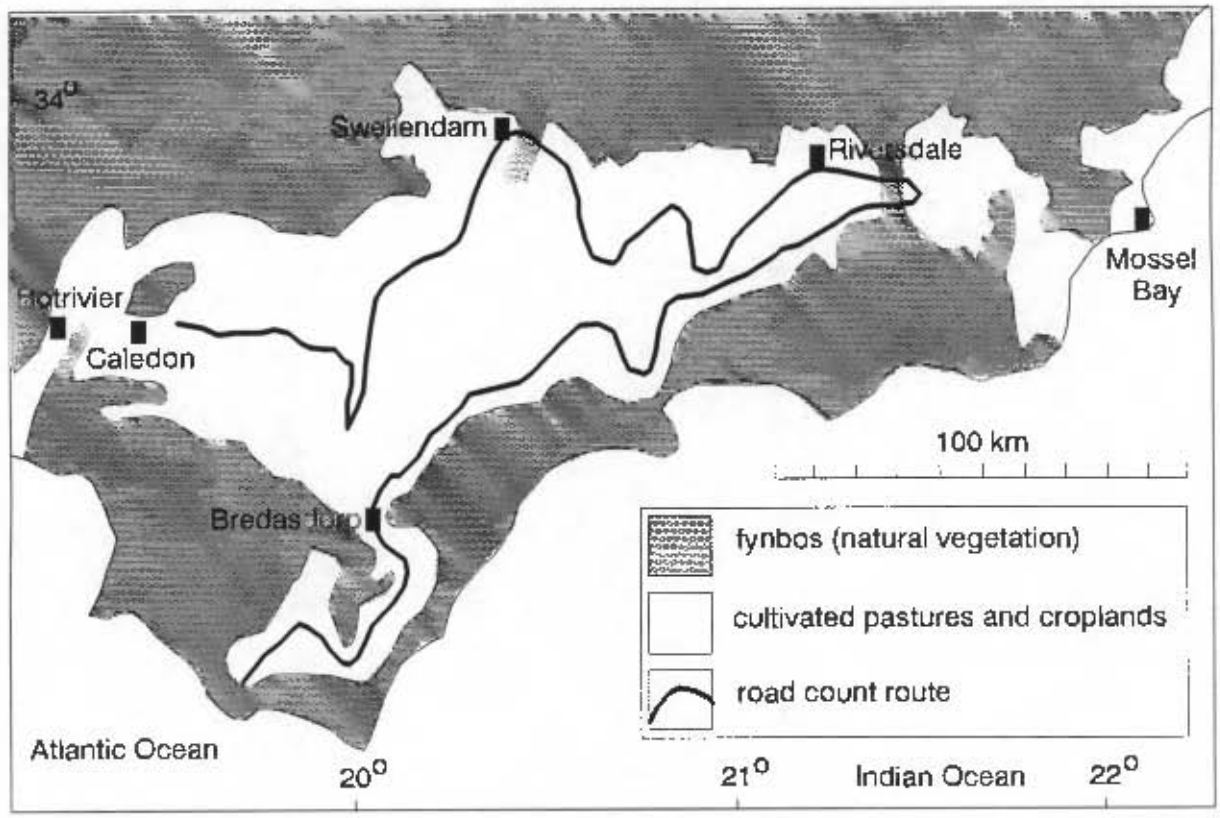

Figure 10.1 The southern Cape study area showing areas of natural vegetation and cultivated areas, and the road count route.

Table 10.1 Dates and distances travelled during road counts through the southern Cape and the number of Stanley's Bustard individuals and groups recorded on each count.

Date		No. km	No. inds	No. inds/ 100 km	No. grps	No. grps/ 100 km
Sep.	1988	483	21	4,4	13	2,7
Jun.	1989	509	126	24,8	33	6,5
Jul.	1989	563	134	23.8	47	8,4
Mar.	1990	576	12	2,1	8	1,4
Jul.	1990	564	94	16,7	22	3,9
Nov.	1990	588	19	3,2	8	1,4
Feb.	1991	583	46	7,9	12	2,1
May	1991	605	102	16.9	29	4,8
Jul.	1991	596	80	13,4	22	3,7
Nov.	1991	584	19	3,3	7	1,2
Mar.	1992	581	45	7,8	13	2,2
Jun.	1992	580	127	21,9	26	4,5
Aug.	1992	591	116	19,6	26	4,4
Dec.	1992	593	16	2,7	4	0,7
Apr.	1993	588	125	21,3	24	4,1
Total		**8584**	**1082**	**12,6**	**294**	**3,4**

way, 307 records of habitat use by Stanley's Bustard groups were recorded and these were supplemented by 359 records from volunteer observers and *Promerops*.

Stanley's Bustard males were distinguished from females on the basis of their larger size, thicker necks, unmarked white or grey forenecks and breasts, and plainer upperparts. Females were noticeably smaller, with thinner necks, finely barred forenecks which contrasted with their plain white breasts, and heavily mottled upperparts (Urban *et al.* 1986, Johnsgard 1991, pers. obs). Many of the bustards seen during this study could not be assigned to different age classes, as consistent features differentiating juveniles from adults could not be identified.

On all but the first two counts, the perpendicular distance from the centre of the group of bustards to the transect line (road) was calculated. This was done by measuring the sighting distance using a rangefinder and the sighting angle using a hinged ruler and a protractor. The perpendicular distance was calculated according to the equation $y=r\sin\theta$, where y represents the perpendicular distance, r represents the sighting distance and θ represents the sighting angle (Burnham *et al.* 1980). During the fourth count in the southern Cape damage to a rangefinder necessitated the measuring of perpendicular distances by pacing out distances on foot. These data were used to estimate the density of bustards in the study area using the computer program 'TRANSECT' (Laake *et al.* 1979, Burnham *et al.* 1980).

Breeding records of Stanley's Bustards in the southern Cape were compiled from personal observations of displaying males (see Tarboton 1989 for a description of the display), records of eggs, young and displaying males from volunteer observers, and from the nest record cards of the Southern African Ornithological Society.

Habitat availability, in addition to habitat use, was measured during road counts to assess habitat selectivity by Stanley's Bustards. This was done by recording the habitat types on each side of the road at one kilometre intervals along the route during all except two of the 15 counts. Chi-square goodness-of-fit tests were used to test the selectivity of habitats by bustard groups relative to the availability of the habitats. It was not permissible to compare statistically the availability of each habitat with its selection by individual bustards, as the flocking habits of the species result in non-independence of the information relating to each individual (Alldredge & Ratti 1986). It was permissible, however, to compare statistically the selection of habitats by bustard groups (including 'groups' of one individual) in relation to their availability. The results of the statistical tests presented here therefore refer to habitat selectivity by groups of bustards. Habitat availability in the Swartland was measured in the same way during the two road counts made there in order to search for habitat differences which could explain the absence of Stanley's Bustard in this region.

10.4) *Results*

Abundance

More Stanley's Bustards were recorded during road counts made during the winter (April-August, 19,7/100 km) than during the summer (September-March, 4,5/100 km; Figure 10.2, Table 10.1). This difference was highly significant ($U=0$, $P<0,001$, Mann-Whitney *U*-test) and all winter counts were substantially higher than all summer counts.

The analysis of the road count line transect data using program 'TRANSECT" was restricted to the data from the winter (April-August) transects, due to the clear difference in the number of birds recorded during the summer and winter counts and because too few Stanley's Bustards were recorded during the summer transects for meaningful analysis using program 'TRANSECT'. The winter estimate of density, based on seven transects (totalling 4087 km and 215 sightings of Stanley's Bustards involving 778 individual bustards), was 0,04 Stanley's Bustards/km^2 (95% confidence limits - 0,02-0,05/km^2). The amount of suitable habitat available in the southern Cape, calculated from Moll & Bossi (1983), is 7640 km^2. The total population estimate for the southern Cape in the winter therefore is 956 Stanley's Bustards (95% confidence limits - 464-1447 bustards). Mean sighting distances were significantly greater in the winter than the summer, and for males compared with females, and in groups of five or more individuals compared with groups of one to two individuals (Table 10.2).

No Stanley's Bustards were recorded during 519 km of road counts in the Swartland, nor were any seen during 7738 km of road counts in the succulent Karoo. Stanley's Bustards were recorded on only five occasions during 12182 km of road counts in the Nama Karoo: in the Great Karoo, one group of three birds (32° 57'S, 25° 33'E), another of two birds (33° 04'S, 25° 36'E), and a solitary individual (33° 11'S, 25° 39'E) were recorded on 9 March 1989, and another singleton was seen on 10 July 1989 (33° 11'S, 25° 39'E), and in the Steytlerville Karoo, one flock of six birds (33° 25'S, 24° 43'E) was recorded on 1 July 1988.

Breeding season

Displaying male Stanley's Bustards were recorded in the southern Cape between August and December, mainly in September and October (August - 1, September - 36, October - 19, December - 13). Eggs were recorded in September (n=1) and October (n=3) and unfledged young in September (n=1) and January (n=1).

Sex ratio

The observed sex ratio differed between the breeding (September-December) and non-breeding (February-August) seasons (Figure 10.3). During the breeding season

Table 10.2 Comparison of perpendicular sighting distances measured during line transects of Stanley's Bustards in the southern Cape between the summer (September-March) and winter (April-August), between sightings of males and females, and between groups of one and two individuals and groups of five or more individuals.

	Mean sighting distance	S.D.	median	range	n=
Summer	258[1]	223	214	49-1500	46
Winter	286[1]	191	234	39-1042	234
Males	282[2]	215	225	53-1500	83
Females	236[2]	154	196	39-739	85
Groups of 1-2	265[3]	201	203	50-1500	133
Groups of 5+	332[3]	213	238	85-1042	58

[1] - $z=19{,}51$, $P<0{,}001$
[2] - $z=2{,}27$, $P<0{,}05$
[3] - $z=2{,}79$, $P<0{,}01$

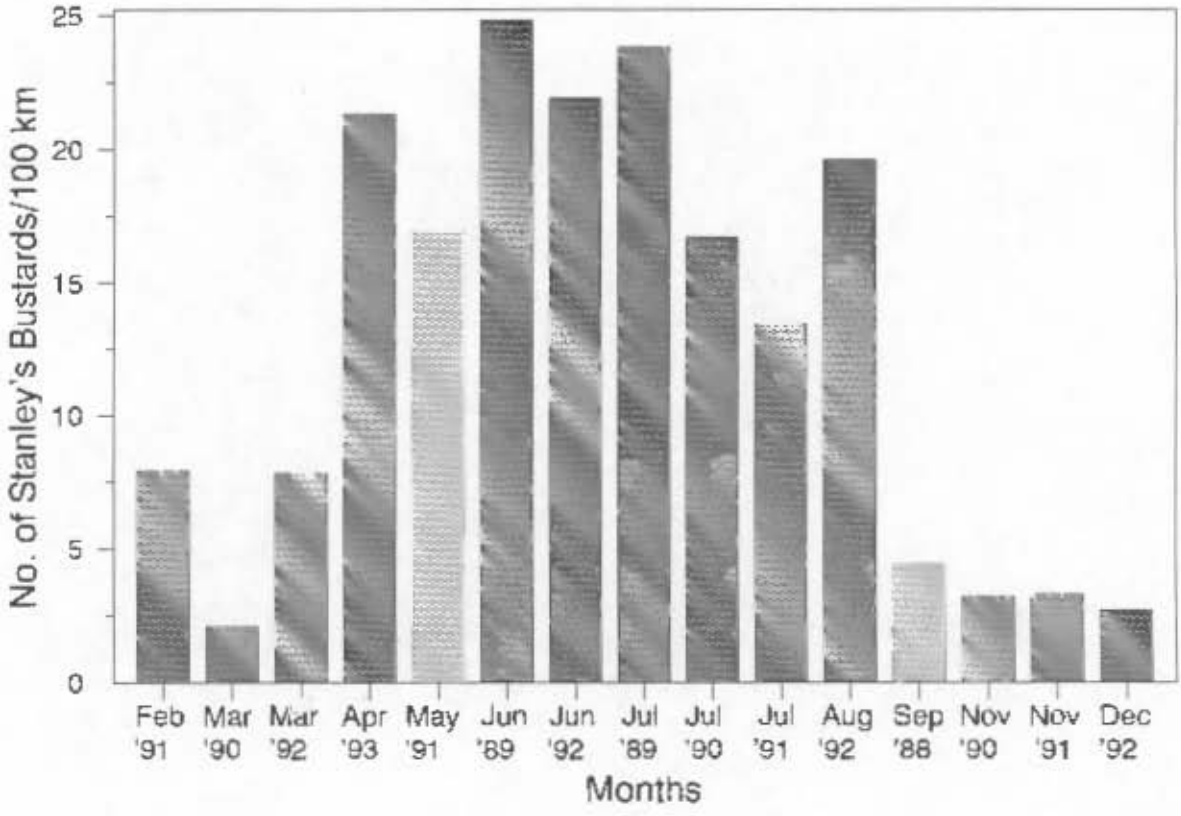

Figure 10.2 The number of Stanley's Bustards counted per 100 km during each of the road counts in the southern Cape.

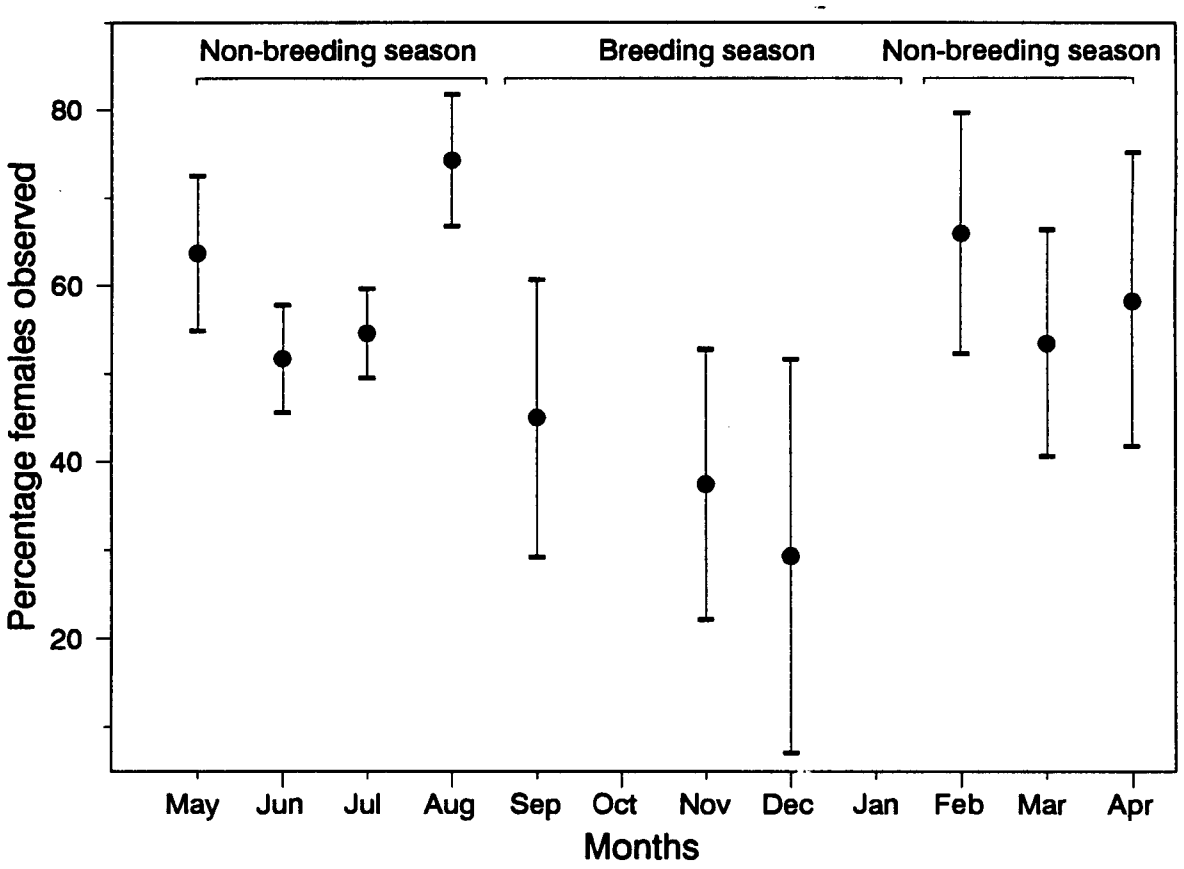

Figure 10.3 The monthly percentage of females recorded relative to the total number of Stanley's Bustards seen in the southern Cape. The error bars denote the 95% confidence limits.

females comprised 38,5% of birds seen (n=96 birds; 1,00 female:1,60 males), while during the non-breeding season females comprised 59,2% of birds seen (n=1139 birds; 1,00 female:0,69 males). During both seasons the sex ratio differed significantly from parity (breeding season - χ^2=4,60, P<0,05; non-breeding season - χ^2=37,98, P<0,001, d.f.=1).

Group sizes

Group sizes were significantly smaller in the breeding season (September-January) than in the non-breeding season (February-August, Tables 10.3 and 10.4, Figure 10.4). In Figure 10.4 derived mean group sizes are shown in order to include 95% confidence limits. The mean group sizes in the breeding and non-breeding seasons were 1,95 and 3,56 respectively, and the median group sizes were one and two individuals respectively. The largest group seen was 28 individuals. Details of the number of groups of different sizes in the breeding and non-breeding periods are shown in Figure 10.5.

Comparison of sociality between sexes and seasons

Stanley's Bustards were significantly more likely to be found alone in summer (September-March) than in winter (April-August, Table 10.5) This was the case for both males and females. Throughout the year, males were significantly more likely to be found alone than were females (Table 10.5). Both sexes tended to form single sex groups when flocking (Tables 10.5, 10.6 and 10.7). During the non-breeding season (February-August), the proportion of single sex male and female groups was significantly higher for all group size categories than would be expected by chance, except for groups of two females (Table 10.7). During the breeding season (September-December), the occurrence of single sex groups of females was significantly more frequent than would be expected by chance, except for groups of two females. The occurrence of single sex groups of males during the breeding season, however, was not significantly higher than would be expected by chance.

Groups comprising one male and one female were extremely rare, and were recorded on only 14 occasions, out of a total of 204 groups (comprising 573 individuals) of two or more birds recorded during this study. In at least five of these sightings the males appeared dull-coloured and possibly were juveniles. In one instance (16 June 1989) a female accompanied by such a male was seen to feed it on several occasions. Considering all groups with two or more individuals and having unequal numbers of each size, the mean size of groups with all and mainly females (6,3, S.D.=5,0, range=2-24, n=106, median=5) was significantly higher than for groups of all and mainly males (4,7, S.D.=3,6, range=2-26, n=81, median=3; z=2,64, P<0,01).

Table 10.3 Mean monthly group sizes of Stanley's Bustards in the southern Cape.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean	2,77	3,21	3,55	4,02	3,21	3,87	3,36	2,99	1,93	1,44	1,95	2,29
S.D.	2,02	4,05	4,63	3,66	2,80	4,44	3,54	3,30	1,58	0,98	1,44	2,65
No. grps	22	38	91	52	84	91	137	69	53	46	58	21
No. inds	61	122	323	209	270	352	460	206	102	66	113	48

Table 10.4 Differences in group sizes in Stanley's Bustards in the southern Cape during the non-breeding (February-August) and breeding (September-January) seasons.

Months	Mean group size	S.D.	Median group size	Modal group size	range	No. of groups	No. of inds
Feb-Aug	3,46*	3,81	2	1	1-28	562	1942
Sep-Jan	1,95*	1,66	1	1	1-12	200	390

* - $F_{199\ \&\ 561} = 1{,}88$, $P < 0{,}001$, F-test

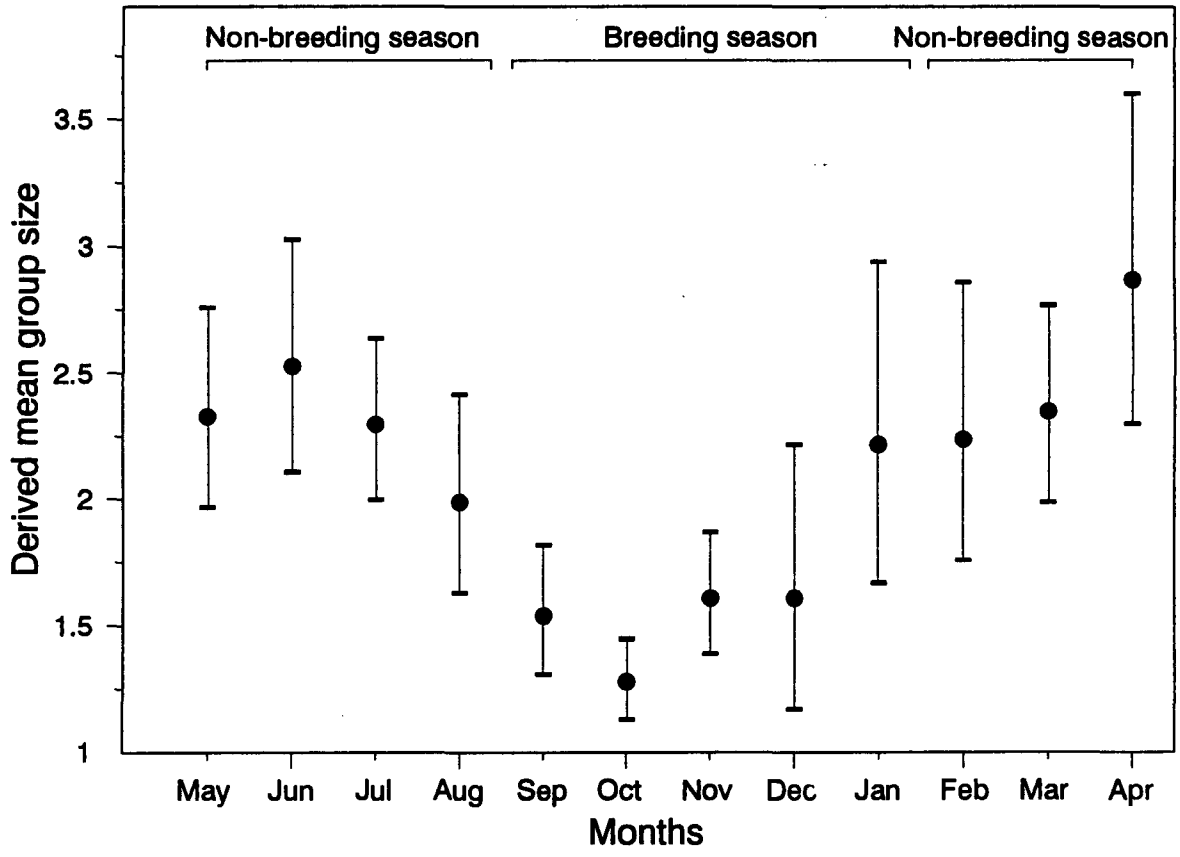

Figure 10.4 The monthly derived mean group size of Stanley's Bustards in the southern Cape. The error bars denote the 95% confidence limits.

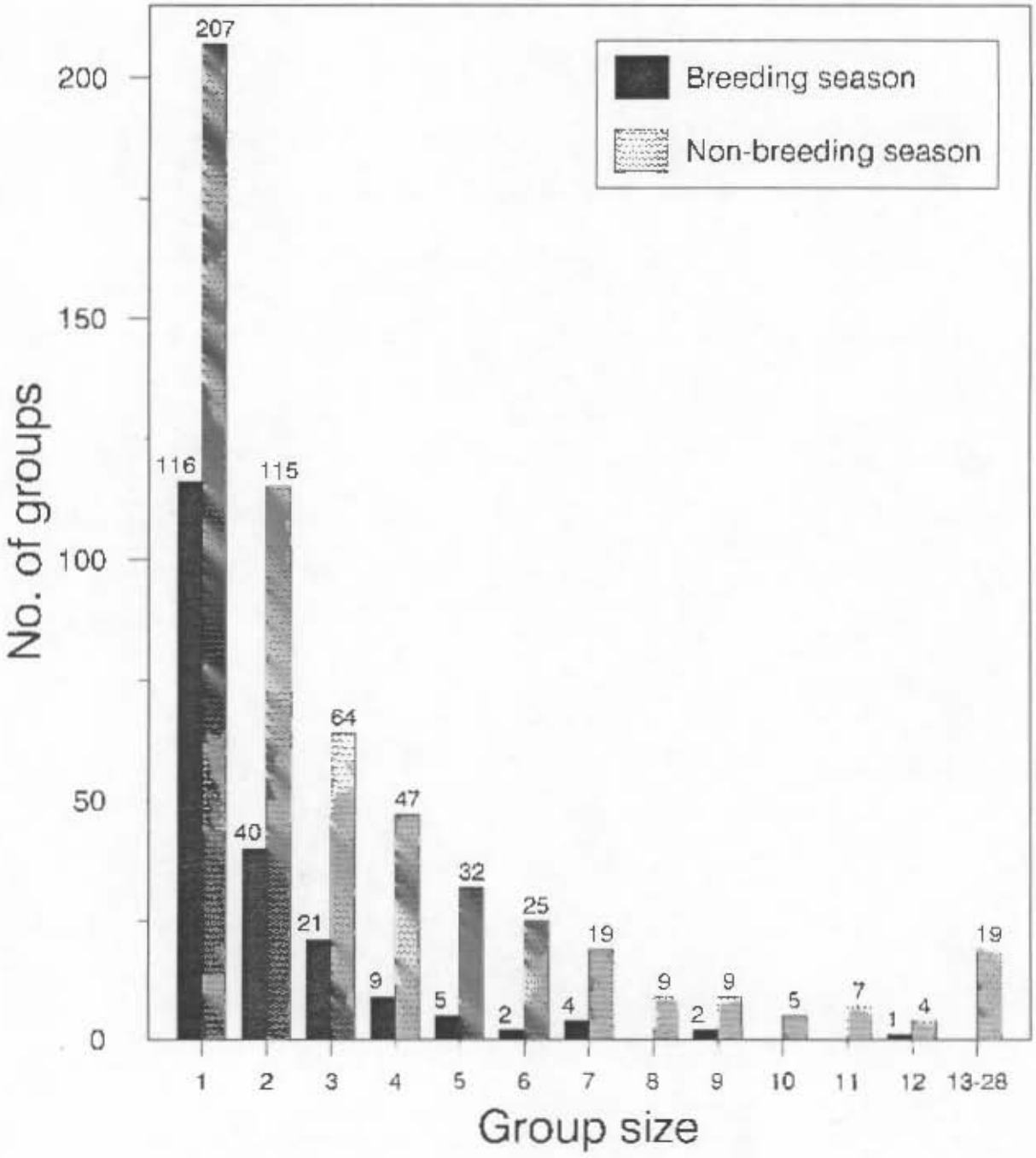

Figure 10.5 The number of Stanley's Bustard groups of different sizes in the southern Cape during the breeding (September-January) and non-breeding (February-August) periods.

Table 10.5 The number and percentage of male and female Stanley's Bustards in the southern Cape that were found solitarily and in all female, mainly female, equal sex, mainly male, and all male groups during the summer (September-March) and the winter (April-August).

	Summer		Winter		Total	
	no.	%	no.	%	no.	%
Males						
Solitary	32	31,4%[1]	54	12,8%[1]	86	16,4%[3]
Mainly female	13	12,7%	70	16,6%	83	15,8%
Equal	7	6,9%	14	3,3%	21	4,0%
Mainly male	13	12,7%	136	32,2%	149	28,5%
All male	37	36,3%	148	35,1%	185	35,3%
Male totals	*102*		*422*		*524*	
Females						
Solitary	13	13,1%[2]	39	6,4%[2]	52	7,3%[3]
All female	25	25,2%	302	49,3%	327	46,0%
Mainly female	48	48,5%	207	33,8%	255	35,9%
Equal	7	7,1%	14	2,3%	21	2,9%
Mainly male	6	6,1%	50	8,2%	56	7,9%
Female totals	*99*		*612*		*711*	

1 - $\chi^2=20,66$, $P<0,0001$, d.f. = 1
2 - $\chi^2=5,74$, $P<0,05$, d.f. = 1
3 - $\chi^2=25,16$, $P<0,0001$, d.f. = 1

Table 10.6 The number and percentage of Stanley's Bustard groups in the southern Cape that comprised singletons, all females, mainly females, equal sexes, mainly males, and all males during the summer (September-March) and the winter (April-August).

	Summer		Winter		Total	
	no.	%	no.	%	no.	%
Solitary	45	56,3%	93	35,5%	138	40,4%
All female	9	11,3%	58	22,1%	67	19,6%
Mainly female	5	6,2%	34	13,0%	39	11,4%
Equal	6	7,5%	11	4,2%	17	5,0%
Mainly male	3	3,7%	27	10,3%	30	8,8%
All male	12	15,0%	39	14,9%	51	14,9%
Totals	*80*		*262*		*342*	

Table 10.7 The number of Stanley's Bustard groups in each group size category that comprised all males, all females, and a mixture of both sexes in the non-breeding (February-August) and breeding (September-December) seasons in the southern Cape.

Group size	All males	All females	Both sexes	$G=$*	$P=$
Non-breeding season					
2	19^{+++}	$17^{n.s.}$	10^{---}	20,36	$P<0,001$
3	12^{+++}	16^{++}	13^{---}	33,81	$P<0,001$
4	7^{+++}	7^{++}	5^{---}	39,81	$P<0,001$
5	4^{+++}	4^{+}	10^{---}	22,89	$P<0,001$
6	3^{+++}	5^{+++}	7^{---}	32,97	$P<0,001$
7	1^{+}	3^{++}	7^{---}	16,02	$P<0,001$
8-26	1^{++}	11^{+++}	25^{---}	81,33	$P<0,001$
Breeding season					
2	$1^{n.s.}$	$1^{n.s.}$	$3^{n.s.}$	0,74	n.s.
3-12	$3^{n.s.}$	3^{++}	5^{--}	12,48	$P<0,001$

* - G test, d.f. = 2
+++ - significantly more than expected, $P<0,001$, d.f. = 1
++ - significantly more than expected, $P<0,01$, d.f. = 1
\+ - significantly more than expected, $P<0,05$, d.f. = 1
--- - significantly less than expected, $P<0,001$, d.f. = 1
-- - significantly less than expected, $P<0,01$, d.f. = 1

Habitat selectivity

In the southern Cape, the available habitats varied seasonally according to crop farming practices. Four broad habitat types were identified: cultivated dryland pastures of grasses, scattered lucerne plants, etc. ('pastures'); agricultural crop fields, mainly cereal crops, e.g. wheat, oats, barley, etc. ('croplands'); natural vegetation, i.e. fynbos, renosterveld and strandveld (Moll & Bossi 1983); and a miscellaneous category encompassing alien trees, homesteads, smallholdings, vineyards, orchards, and irrigated crop fields and pastures along rivers. The relative proportions of the study area covered by each habitat type were: pastures - 46,3%, croplands - 33,6%, natural vegetation - 11,3% and miscellaneous - 8,8%. No Stanley's Bustards were recorded in the miscellaneous habitats and they will not be considered further here. The croplands consisted of three types depending on the stage of the crop farming cycle: harvested croplands, croplands with growing crops and recently ploughed croplands. Recently ploughed croplands were most common in April to May, the sowing season, but also were present throughout the rest of the year at lower frequencies (Table 10.8, Figure 10.6). Croplands with growing crops were present mainly between June and September, in the period immediately following sowing. Harvested croplands ('stubble fields') were present mainly from November to March, with some remaining during April and May.

Stanley's Bustards were selective in their use of these various habitats (Tables 10.8 and 10.9, Figures 10.6 and 10.7). Pastures were used in proportion to their availability during the summer (September-March) but were significantly favoured during the winter (April-August). Natural vegetation was significantly favoured during the breeding season (September-December) but was significantly avoided during the remainder of the year. Harvested cereal croplands were significantly favoured during the period when they were available (November-March). Ploughed croplands, which were available all year, and fields with growing cereal crops, which were available between June and September, were significantly avoided.

The patterns of habitat availability in the Swartland, i.e. pastures - 34,9%, croplands - 46,9%, natural vegetation - 1,6% and miscellaneous - 16,5%, differed from those in the southern Cape (pastures - 46,3%, croplands - 33,6%, natural vegetation - 11,3% and miscellaneous - 8,8%), with the Swartland having more croplands and miscellaneous habitats and less pastures and natural vegetation. The types of crops in the two areas were similar, i.e. largely cereal crops, and the croplands consisted of harvested fields, fields with growing crops and ploughed fields, the relative proportions of which depended on season.

Table 10.8 The monthly availability of five different habitat types in the southern Cape and their use by groups of Stanley's Bustards. The sample sizes in the final column refer to the number of data points used in assessing habitat availability and the number of Stanley's Bustard groups recorded in each month. No data on habitat availability were collected in January or October.

Month		% cult. pastures	% harv. cereal	% grow. cereal	% plough. fields	% nat. veg.	n=
January	Hab. avail.						
	Hab. used	**21,0**	**73,7**	**0**	**0**	**5,3**	**19**
February	Hab. avail.	52,9	23,3	0,1	11,3	12,4	1028
	Hab. used	**47,1**	**44,1**	**0**	**2,9**	**5,9**	**34**
March	Hab. avail.	52,4	21,4	0	13,5	12,7	1901
	Hab. used	**53,2**	**24,7**	**7,8**	**5,2**	**9,1**	**77**
April	Hab. avail.	47,1	12,2	1,1	26,7	12,9	1171
	Hab. used	**77,5**	**18,4**	**0**	**4,1**	**0**	**49**
May	Hab. avail.	45,1	11,8	1,5	29,0	12,6	1226
	Hab. used	**68,7**	**11,9**	**6,0**	**13,4**	**0**	**67**
June	Hab. avail.	52,1	0,6	25,5	8,8	13,0	1245
	Hab. used	**66,7**	**0**	**28,4**	**4,9**	**0**	**81**
July	Hab. avail.	48,9	2,6	35,8	0,6	12,1	1922
	Hab. used	**73,9**	**1,7**	**22,7**	**0**	**1,7**	**119**
August	Hab. avail.	50,1	0	34,6	1,5	13,8	1139
	Hab. used	**67,1**	**0**	**22,4**	**1,5**	**9,0**	**67**
September	Hab. avail.	48,0	0	37,6	2,5	11,9	918
	Hab. used	**53,2**	**0**	**8,5**	**0**	**38,3**	**47**
October	Hab. avail.						
	Hab. used	**50,0**	**0**	**7,9**	**0**	**42,1**	**38**
November	Hab. avail.	56,1	26,8	2,0	4,0	11,1	2043
	Hab. used	**53,1**	**22,4**	**2,0**	**0**	**22,5**	**49**
December	Hab. avail.	50,4	31,1	0,6	5,7	12,2	1213
	Hab. used	**15,8**	**57,9**	**0**	**0**	**26,3**	**19**

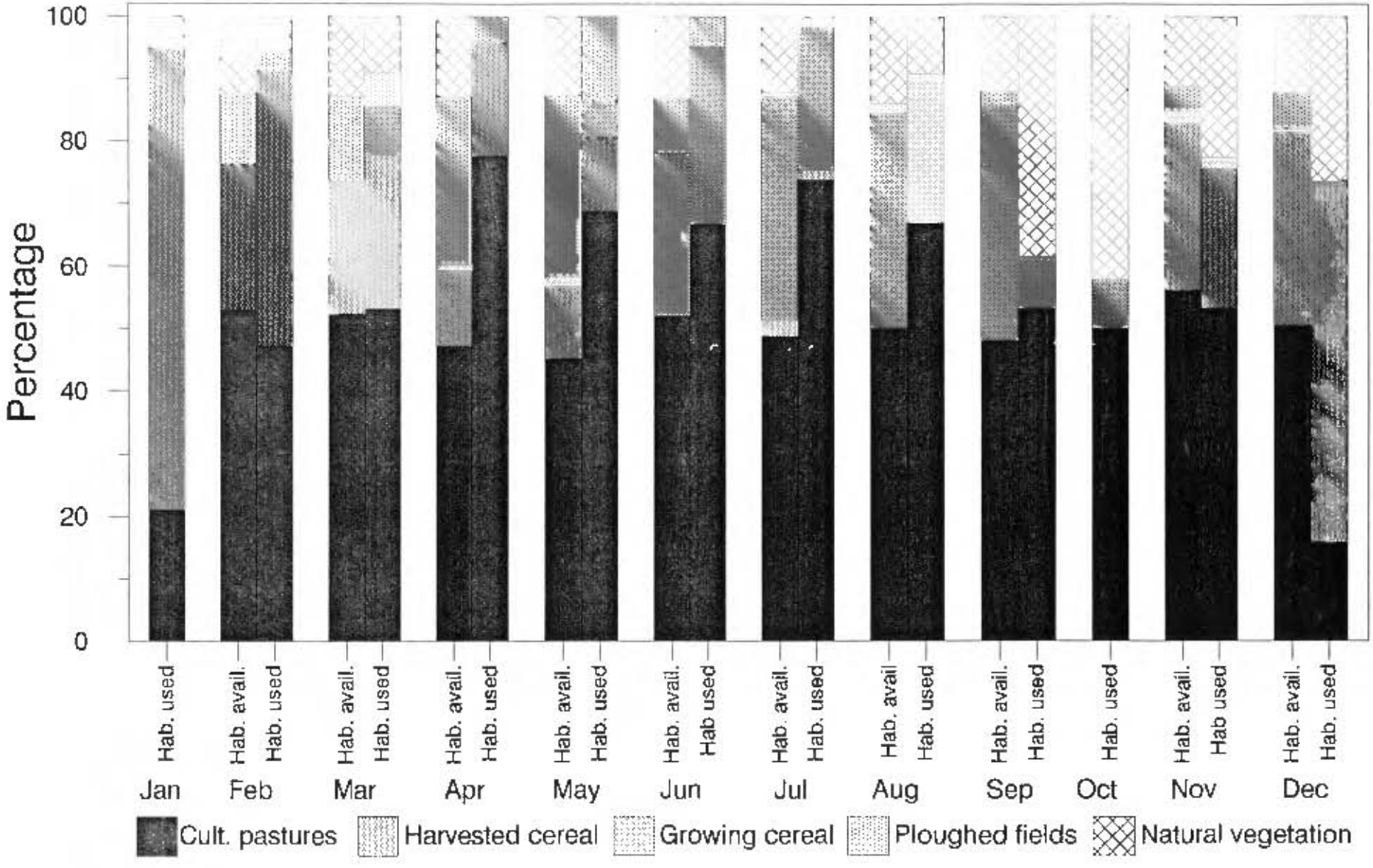

Figure 10.6 Monthly availability and use of five habitats by Stanley's Bustards in the southern Cape.

Table 10.9 Summary of patterns of habitat selection by Stanley's Bustard groups in the southern Cape.

Habitat	Avail-ability		Obs.	Exp.	n=	χ^2=	P^*=	Selection
Pastures	all year	Apr.-Aug.	271	186,5	383	38,75	<0,001	positive
		Sep.-Mar.	134	147,2	283	1,23	>0,05	neutral
Harvested fields	Nov.-Mar.		70	50,9	198	4,34	<0,05	positive
Growing cereal	Jun.-Sep.		69	104,9	314	10,25	<0.01	negative
Ploughed fields	all year		21	69,3	666	27,72	<0,001	negative
Natural vegetation	all year	Sep.-Dec.	50	17,9	153	19,50	<0,001	positive
		Jan.-Aug.	18	65,6	513	29,51	<0,001	negative

* - d.f. = 1 in all Chi-square goodness-of-fit tests

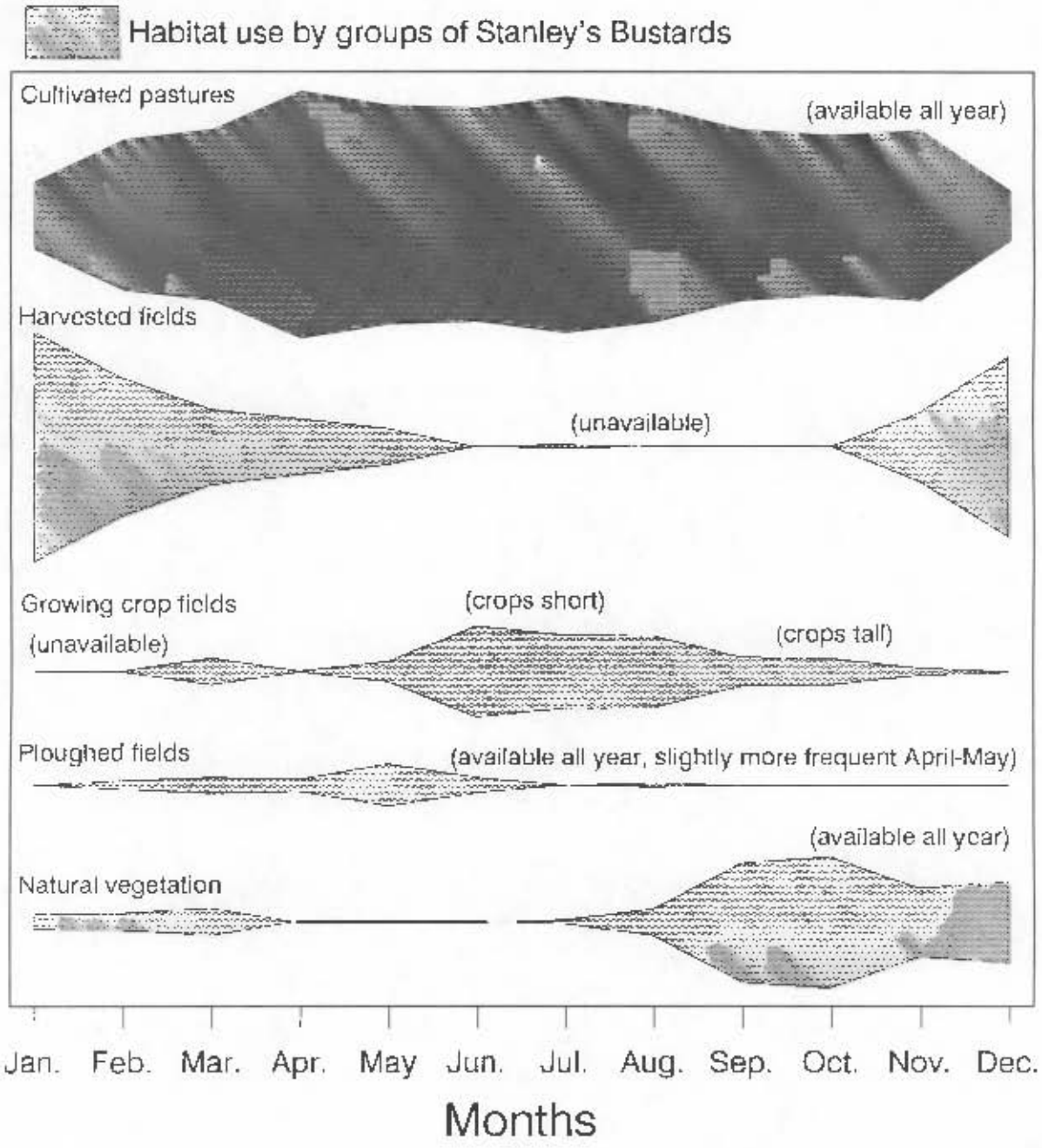

Figure 10.7 Summary of use and availability of five habitats by Stanley's Bustards in the southern Cape.

10.5) *Discussion*

Several factors may have been responsible for the higher number of Stanley's Bustards counted during road counts in the southern Cape in the winter than in the summer. The species reportedly shows altitudinal movements (Herholdt 1988), moving to lower-lying areas during the winter. It is possible that there was a winter influx of birds to the coastal study area from higher-lying regions to the east.

Other factors, however, related to conspicuousness also could have been responsible for the lower numbers of bustards counted in the summer and these are listed below.

1) Changes in habitat use could have been involved, specifically the movement into natural vegetation during the summer breeding season. The road count route probably was biased towards travelling through agricultural areas and, to at least some extent, avoided the less accessible areas of natural vegetation. In addition, Stanley's Bustards probably were far less conspicuous in the taller, denser natural vegetation compared with the shorter pastures and croplands.

2) During the course of fieldwork, it was thought that Stanley's Bustards were more visible during the winter in the pastures and croplands, due to the nature of the background vegetation. In winter the vegetation in the pastures and croplands appeared uniformly short and bright green, whereas in the summer it appeared more heterogenous in height and coloured in various shades of (dry) brown. The shorter mean perpendicular sighting distance (based almost exclusively on birds seen in the pastures and croplands) in the summer than in the winter confirmed this impression. It also was possible that Stanley's Bustards were more active in the winter than in the summer, due to the cooler weather or having to spend more time foraging, and therefore more likely to have been seen.

3) During the summer breeding season, females with eggs and young were likely to become more secretive in their habits. Males, however, which indulge in conspicuous displays during the breeding season may have been more visible at this time.

4) The perpendicular sighting distance data showed that larger groups of bustards were more conspicuous than smaller groups. The mean flock size was higher in winter than in summer and this may have contributed to the higher winter road counts.

The small number of Stanley's Bustards counted during road counts in the Karoo and the restriction of these records to the non-breeding season, confirms Herholdt's (1988) finding that the species is a non-breeding vagrant to this region and is found only

in those parts of the Karoo that are adjacent to the fynbos and sour grassland biomes. There are few other population estimates for Stanley's Bustard in South Africa to compare with that for the southern Cape (464-1447 individuals). The Transvaal breeding population probably numbers less than 300 individuals (Tarboton *et al.* 1987) and that in the eastern Cape Province 100-200 birds (Urban *et al.* 1986). The species is now rare or absent throughout most of Transkei, although a small population, estimated at over 30 "pairs" (Butchart 1989), persists in the Luchaba Nature Reserve (400 ha) near Umtata (Quickelberge 1989). Personal observations confirmed this rarity in Transkei. I visited this region four times between September 1990 and February 1992 (Sept.-Oct. 1990, March 1991, Sept.-Oct. 1991, Feb. 1992) to survey birdlife there. Fifty-eight of the approximately 85 (68%) quarter degree grid squares (15'X15') covering this region were visited, 55 days were spent in the field and about 11 800 km were travelled. Stanley's Bustards were recorded on only seven occasions, twice at Luchaba Nature Reserve. All sightings were of one to three birds. The distribution of Stanley's Bustard in the Orange Free State is limited to the extreme northeast of this province (Herholdt 1988). The species is relatively widespread in Natal (Cyrus & Robson 1980) but no population estimate exists. In Swaziland, the total population estimate is 20 birds; Stanley's Bustard is restricted as a breeding species to the Malolotja Nature Reserve and is a vagrant elsewhere in the country (Parker in press). In Lesotho, Stanley's Bustard is a rare non-breeding visitor (Osborne & Tigar 1992). This threatened sub-species is not found outside the above-mentioned regions and its total population size is unlikely to exceed 5000 individuals.

The difference in sex ratio between winter (1 female:0,69 males) and summer (1 female:1,60 males) probably was due to changes in the relative conspicuousness of the sexes between the two seasons. Females probably became more secretive during the summer breeding season, while males probably became more conspicuous in the summer due to their breeding displays. At all times, the markedly larger body size of males (Johnsgard 1991) probably would have rendered them more visible than females. This was confirmed by the perpendicular sighting distance data, with the mean sighting distance to males being significantly higher than to females. Therefore the observed winter sex ratio, i.e. a preponderence of females, probably was more accurate than the summer ratio, but still was likely to have under-estimated the proportion of females to an unknown extent. This bias may have been balanced to some extent by the tendency for females to form larger groups, which the sighting distance data show were significantly more conspicuous than smaller groups. Female-biased sex ratios have been reported for several other bustards, e.g. the Little *Tetrax tetrax* (Schulz 1986), Great *Otis tarda* (Ena *et al.* 1985) and Great Indian Bustards *Ardeotis nigriceps* (Rahmani & Manakadan 1986).

There is some controversy as to whether Stanley's Bustard is monogamous or polygamous (Wilson 1972, Tarboton 1989, Johnsgard 1991). The paucity of sightings of 'pairs' during this study was strong evidence for polygamy in this species, and was in marked contrast to a study of the race *jacksoni* in Malawi, where apparent pairs were the most commonly seen 'groups' (Wilson 1972). The absence of pair formation in the southern Cape accords with evidence for polygamy from observations of breeding birds in the Transvaal (Tarboton 1989), and from the marked sexual dimorphism found in Stanley's Bustards (Johnsgard 1991). In the light of this evidence for polygamy, the observations of Wilson (1972) would appear to require confirmation. Polygamy is the usual mating system in bustards, at least in the larger species (Johnsgard 1991). In the Great Indian Bustard, sightings of a single male and a single female together usually comprised a female with a juvenile offspring (Rahmani & Manakadan 1986), a situation similar to that found in this study. The observation of a female feeding a juvenile male during the winter (at least six months after the end of the normal egglaying period), suggests that juvenile Stanley's Bustards remain with their female parent for several months after fledging. The strong tendency shown by both sexes to live solitary lives during the breeding season and to form single-sex groups when flocking has been reported for several other large bustard species, e.g. the Great Bustard (Martinez 1988).

Stanley's Bustards in the southern Cape inhabit a mosaic of cultivated pastures, agricultural croplands and natural vegetation and exploit all of these habitats, with clear seasonal differences in their use of each habitat. This adaptation to an agricultural landscape also is typical of several other large bustard species, e.g. the Great Bustard in Hungary (Farago 1988). The slight differences between the southern Cape and the Swartland in the relative abundance of cultivated pastures and croplands does not explain the absence of the species from the Swartland. It is possible that the paucity of patches of natural vegetation in the Swartland excludes the species from this area. In the southern Cape study area, which had a higher proportion of natural vegetation, there was a clear selection for these areas during the breeding season. This dichotomy in patterns of abundance between the western and southern parts of the southwestern Cape agricultural regions, despite their superficial similarity, is shown by several other large terrestrial birds, i.e. Blackheaded Heron *Ardea melanocephala*, White Stork *Ciconia ciconia*, Blue Crane *Anthropoides paradiseus* (Chapter 3), Karoo Korhaan *Eupodotis vigorsii*, and Black Crow *Corvus capensis* (Hockey *et al.* 1989), all of which are common in the southern Cape but are uncommon or absent in the Swartland. At least one of these species, however, the Blue Crane (Chapter 6), is not reliant on natural vegetation at any time in either region. This suggests that the paucity of natural vegetation in the Swartland may not be the primary cause of, or at all implicated in, the absence of Stanley's Bustards from the area.

Several sources of unnatural mortality to Stanley's Bustard in the southern Cape and elsewhere in its range were identified during this study and some of these already have been recognised by other observers (Table 10.10). The danger posed by overhead transmission lines also has been identified as a threat to the Ludwig's (Allan 1988, Herholdt 1988) and Great (Tapias 1980, Ena *et al.* 1985) Bustards. At least one line of steel electricity pylons and lines, over 100 kilometres in length, was constructed in the southern Cape during this study (pers. obs.) and at least one other is planned (B. Lawson, South African Electricity Supply Commission). The impact of such constructions in this area, and elsewhere, on Stanley's Bustards and other large birds requires investigation. The ubiquitous injury and mortality caused to a wide range of birds by barbed-wire fences has been reviewed by Allen (1990).

Another, probably more serious, threat is habitat destruction, either through continual disturbance or due to intensive monocultural crop farming and commercial afforestation. The scarcity of the species in Transkei can be at least partly attributed to human disturbance (Quickelberge 1989). Johnson (1989) has stressed the danger posed to Stanley's Bustards and other grassland birds by the extensive afforestation of grassland habitats in Natal, and Tarboton (1989) similarly identified the planting of alien trees as a threat to the species in the Transvaal. Both Herholdt (1988) and Tarboton (1989) identified intensive crop farming as a threat. The species is legally protected throughout South Africa and hunting pressure is thought to be insignificant (Herholdt 1988), but direct information on this point is lacking. There is a clear consensus that Stanley's Bustard has decreased in abundance in South Africa (Brooke 1984, Herholdt 1988, Tarboton 1989). Other races of Stanley's Bustard found further north in Africa also have decreased and hunting has been implicated as a major cause of the extirpation and decrease in many areas (Johnsgard 1991). Commercial afforestation is likely to be the major threat to the remaining South African populations, at least in the sour grasslands of the Transvaal, Natal and eastern Cape.

In the southern Cape region inhabited by Stanley's Bustards, commercial afforestation is minimal due to the governmental policy of discouraging this practice in crop farming regions and because rainfall is too low (<875 mm/annum) for extensive forestry (Anon. 1982). Although crop farming is widespread in the area, there are patches of natural vegetation and large areas of pastures used for small stock grazing. It is likely that this mosaic of habitats is responsible for the persistence of the species in the southern Cape, which might otherwise have become extinct in the region in the face of the habitat changes wrought by extensive monocultural crop farming or commercial afforestation at the cost of natural vegetation and stock farming.

Table 10.10 Causes of unnatural mortality in Stanley's Bustards in South Africa. Four causes are listed, i.e. aerial collisions with overhead transmission lines, entanglement in fences, snares, and poisoning by eating poisoned grain put out to kill Helmeted Guineafowl *Numida meleagris* for food.

Cause	No.	Sex	Locality	Date	Source
Trans.	1	M	sthn Cape	Mar. 1992	pers. obs.
line	1	M	sthn Cape	Sep. 1988	H.A. Scott (pers. comm.)
	1	F	east. Cape	Apr. 1965	East London Museum specimen
	1	F	east. Cape	Oct. 1984	(Vernon 1985)
	1	M	Transvaal	Oct. 1987	Transvaal Museum specimen
Fence	1	M	sthn Cape	Apr. 1993	pers. obs.
	1	?	east. Cape	Feb. 1988	D. Scheepers (pers. comm.)
Snare	2	?	Transvaal	Winter 1978	Mendelsohn (1978)
	1	?	Natal	Jun. 1972	Herholdt (1988)
	1	?	Natal	Nov. 1986	P.J. van Zuydam (pers. comm.)
Poison	1	?	Natal	Autumn 1988	Guy (1988)

SYNTHESIS

SYNTHESIS

The inclusion of cranes and bustards within the ambit of a single study would at first glance seem inappropriate. Cranes traditionally are thought of as wetland birds, while bustards are associated with arid to semi-arid terrestrial environments. There are sound ecological, phylogenetic and conservation reasons, however, for simultaneously studying the Blue Crane and Ludwig's and Stanley's Bustards.

Ecologically, the Blue Crane is an unusual member of its family, as it is independent of wetland habitats for both feeding and breeding. Its habitat and distribution in fact overlap with that of the two bustards, rather than with other cranes. Indeed, the Blue Crane is found in the semi-arid eastern Karoo (annual rainfall 200-500 mm), a region too dry for the Stanley's Bustard, which prefers relatively high rainfall (>500 mm/annum) regions compared to most bustards. The habitat requirements of the Blue Crane therefore partially overlap with those of both Ludwig's and Stanley's Bustards, rather than lying at or beyond the extremes of the habitat continuum occupied by the two bustards. A comparison of Figures 6.3 and 10.7 shows the extensive overlap in habitat choice between the Blue Crane and Stanley's Bustard in the southern Cape. All three species are highly mobile, with complex and adaptable patterns of movements, the fine details of which still require investigation. Cranes and bustards are both omnivorous, at least to some extent, but the diets of the Blue Crane and Ludwig's and Stanley's Bustards, and the influence of diet on their relative life history strategies, remain poorly known.

Recent DNA-DNA hybridization studies confirm the close phylogenetic relationship of cranes and bustards. An interesting difference between the Blue Crane and Ludwig's and Stanley's Bustards lies in their relative conspicuousness when breeding. The bustards are extremely secretive at the nest, the plumage of females is highly cryptic, and nests are well concealed. By contrast, the plumage of the Blue Crane is in no way cryptic and it frequently nests in exposed positions where the incubating adult is highly visible. This poses the question as to why the Blue Crane apparently is indifferent to the threat posed by predators when it is breeding, despite its having abandoned the safety of wetland habitats when nesting.

The mating systems of cranes and large bustards also contrast. Cranes are territorial and monogamous, while large bustards are non-territorial and polygamous. An effect of these different social strategies can be seen in the contrasting group size data presented for the Blue Crane (Figure 5.1) and the Stanley's Bustard (Figure 10.5). Blue Cranes are rarely found alone. Breeding adults usually live in pairs and family parties, and non-breeders reside in large flocks. Stanley's Bustards are frequently found alone and flocks usually tend towards single sex groupings. Why large bustards form single sex

groups is unknown, but may relate to differences between the sexes in diets, foraging times, and habitat selection. Perhaps the large sexual size dimorphism, concomitant with their mating system, results in differences in preferred walking speeds that makes it untenable for males and females to consort while foraging. Possibly subtle social reasons are involved. That monogamous Blue Cranes have an even sex ratio, while the polygamous Stanley's Bustards have a female-biased sex ratio is not surprizing. Possibly the need for conspicuousness, relative to conspecifics, in the defence of territories by Blue Cranes is responsible for their non-cryptic plumage and even their choice of exposed nest sites. The large number of non-breeders in Blue Crane populations, which possible exert a heavy pressure on territory holders, supports this suggestion. A key question is whether these non-breeders are physiologically capable of breeding but are excluded from establishing breeding territories by the established breeders, or whether they are physiologically too young for reproduction.

It is typical in biology to be faced with the apparent paradox of similar species, such as the Blue Crane and the Ludwig's and Stanley's Bustards, which inhabit similar and often overlapping habitats and apparently pursue the same food, but which differ dramatically in aspects of their life histories, for example in this case their mating systems. The key to understanding these enigmas may lie in an appreciation that different but adequate solutions to the same problem are sufficient and that the single optimal solution need not evolve in all instances where adequacy suffices for survival. In addition, species do not arise out of a vacuum but come from a phylogenetic lineage that frequently predisposes them to adopting particular strategies. In the case of the Blue Crane, the unexploited research interest is to investigate the impact of the wetland origins of this species on its dryland life style.

During this study, it frequently was possible to gather data on all three species simultaneously using the same methods. In particular, observations made during road counts were found to be a successful way of investigating many aspects of their biology. The inclusion of bird atlas data, especially reporting rates, was fruitful. On one hand, atlas data provided an invaluable insight into the distribution and abundance of Blue Cranes and Ludwig's Bustards throughout their ranges. On the other hand, the data from other aspects of the study provided useful information on the interpretation of atlas reporting rates. The evidence confirming that reporting rates reliably reflect abundance was reassuring and necessary, as this has not been tested previously. The measures of density coming out of road counts, line transects and aerial censuses could be extrapolated over the entire ranges of these two species, using reporting rates as a guide. This is the first time that reporting rates have been used as an aid in estimating total population sizes, although the possibility was suggested by Osborne & Tigar (1992). The inaccuracy of reporting rates in reflecting the movements of Blue Cranes

emphasized the need for caution in the interpretation of some atlas data and the need for independent confirmation of reporting rate data wherever possible.

The logarithmic relationship found between abundance and reporting rates has profound implications for interpreting atlas data. For example, a threefold increase in reporting rates of Ludwig's Bustards between the summer and winter in the succulent Karoo reflected a staggering 45 times increase in density as measured by road counts. At the lower scale of a species' density, large changes in reporting rates reflect relative small changes in density. At the higher scale of a species' density, small changes in reporting rates reflect relatively large changes in density. In areas where a species is relatively scarce, differences in reporting rates should not be over-emphasized. In areas where a species is common, reporting rates are relatively insensitive to large differences in abundance, i.e. between areas where it is common *versus* abundant.

Both cranes and bustards are taxa of conservation concern. The threats faced by the Blue Crane and the two bustards, in particular Stanley's Bustard, are remarkably similar. Both the Blue Crane and Stanley's Bustard have retreated in the face of the high human densities in Transkei (and probably in Swaziland and Lesotho). This is particularly worrying considering the rapid pace of human population expansion in South Africa. Recent political developments in the region are likely to facilitate the expansion of such dense human settlement into other areas, previously 'protected' by iniquitous apartheid legislation. Commercial afforestation similarly poses a grave threat to both species. Despite the recognition of the potential environmental disaster posed by the burgeoning afforestation of grassland ecosystems, little research or conservation effort has focussed on this problem. The impact of collisions with overhead transmission lines on populations of all three species also requires full investigation. This threat can only increase in significance, along with the policy of the South African Electricity Supply Commission to provide electricity to every household in South Africa. Blue Cranes are only one of many birds, and other wildlife, threatened by poisons. The ways in which poisons come into natural environments are as varied as the number of species threatened by them, and range from the intentional aerial poisoning of Redbilled Queleas *Quelea quelea* to the unintentional poisoning of birds brought about by the negligent application of agricultural pesticides. The battle to protect wildlife from these substances and the people who use them will always be ongoing.

The abundance of the Blue Crane in the eastern Karoo and the agricultural areas of the fynbos biome, compared with the grassland biome which has traditionally been seen as the core of its range, is interesting. It is ironic that these two areas, one an ecotone (sub-optimal?) habitat between the grassland and Karoo biomes and the other an anthropogenically highly modified environment are becoming the last strongholds of this grassland species. It is likely that the eastern Karoo also will provide major strongholds

for other grassland species that extend marginally into this region, e.g. the Blue Korhaan *Eupodotis caerulescens*, as the grassland biome is further destroyed and fragmented. Stanley's Bustard also is less threatened in the agricultural parts of the fynbos biome than in the sour grassland regions which comprise the bulk of its range.

The Blue Crane was not included in the South African Red Data Book (Brooke 1984), as the species did not appear threatened at that time. The recent evidence of a widespread decrease in the grassland biome suggests that the species now should be considered as threatened. Accurate censuses of its grassland populations are an urgent priority. By contrast, Ludwig's Bustard was included in the Red Data Book but recent evidence (Herholdt 1988) suggests that this was based on an inaccurate assessment of its putative former distribution. The level of threat faced by the species appears relatively low at present, the total population estimate (Chapter 9) is relatively high, and its arid habitat appears secure from the dangers posed by high human population densities, crop farming and commercial afforestation. Nevertheless, it probably should still be regarded as a threatened species until it can be convincingly demonstrated otherwise. Stanley's Bustard also was included in the Red Data Book and all evidence confirms that this taxa is critically threatened. Its small population size, relatively restricted range, and highly threatened habitat make Stanley's Bustard a prime candidate for extinction within the foreseeable future. Assessments of its population size and conservation status in the grassland biome are pressing urgencies for future research.

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